SCIENTIFIC AGRICULTURE

VOLUME 30 NOVEMBER, 1950 No. 11

SOIL FERTILITY STUDIES

II. MANURE AND FERTILIZERS FOR POTATOES AT CHARLOTTETOWN, P.E.I.[1]

L. E. Wright[2], D. C. Schurman[3] and H. J. Atkinson[4]

[Received for publication July 27, 1950]

OUTLINE OF EXPERIMENT

An investigation to obtain information with respect to the use of manure and chemical fertilizers for the production of potatoes in Prince Edward Island was begun at the Dominion Experimental Station at Charlottetown in 1927. The soil on which the plots were located was a brownish-red fine sandy loam. Analysis of 24 samples of surface soil collected at the beginning of the experiment showed an average pH value of 5.0 and an average nitrogen content of 0.17 per cent.

The plot area was laid out as shown in Figure 1. There were 24 plots, each 13.2 feet by 82.5 feet (1/40th acre), with 4-foot paths between plots. On plots 1 to 6, potatoes were grown continuously. On the remaining 18 plots, a three-year rotation of potatoes, grain and clover was followed. The rotation was begun in 1927 with potatoes on plots 7 to 12 and wheat on plots 13 to 24. In 1928, wheat was grown on plots 13 to 18 and potatoes on plots 19 to 24. Wheat was grown up to and including 1936. Barley was sown in 1937 and has been grown as the grain crop since that time.

[1] Joint contribution from the Division of Chemistry, Science Service and the Division of Field Husbandry, Experimental Farms Service. Scientific contribution No. 183, Division of Chemistry.
[2] Formerly Chemist in charge, Soils and Fertilizers Unit, Division of Chemistry, Science Service, Ottawa.
[3] Assistant (Field Husbandry), Dominion Experimental Station, Charlottetown, P.E.I.
[4] Chemist, Division of Chemistry, Science Service, Ottawa.

Figure 1.—Plan of Experiment

(North)

							L	I	M	E		S	T	R	I	P							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	D	O	U	B	L	E		T	R	E	A	T	M	E	N	T		S	T	R	I	P	
Continuous Potatoes						Rotation Potatoes—'48						Rotation Barley—'48						Rotation Clover—'48					

Plots 1, 7, 13, 19—Check
" 2, 8, 14, 20—Manure
" 3, 9, 15, 21—NPK ($NaNO_3$)
" 4, 10, 16, 22—NPK ($(NH_4)_2SO_4$)
" 5, 11, 17, 23—Manure + NPK ($NaNO_3$)
" 6, 12, 18, 24—Manure + NPK ($(NH_4)_2SO_4$)

Table 1.—Comparison of yields of potatoes grown continuously with yields of potatoes grown in rotation under different fertilizer treatments

(Average for 22 years—1927–48 inclusive)

Treatment	Continuously		In rotation	
	Yield (bu./ac.)	% market.	Yield (bu./ac.)	% market.
1. Check	77	60	143	68
2. Manure	249	84	270	84
3. NPK ($NaNO_3$)	179	76	233	83
4. NPK ($(NH_4)_2SO_4$)	111	72	204	80
5. $\frac{1}{2}$ Manure $\frac{1}{2}$ NPK ($NaNO_3$)	239	82	262	84
6. $\frac{1}{2}$ Manure $\frac{1}{2}$ NPK ($(NH_4)_2SO_4$)	235	81	252	84

The following treatments have been used: (1) Check, no treatment; (2) 15 tons of manure per acre; (3) 1000 lb. of a 4–8–8 fertilizer per acre, using nitrate of soda as a source of nitrogen; (4) 1000 lb. of a 4–8–8 fertilizer per acre, using sulphate of ammonia as a source of nitrogen; (5) 7½ tons of manure and 500 lb. of 4–8–8 fertilizer per acre, using nitrate of soda as a source of nitrogen; (6) 7½ tons of manure and 500 lb. of a 4–8–8 fertilizer per acre, using sulphate of ammonia as a source of nitrogen. The treatments were not randomized but were applied to the plots in the order given above, plots 1, 7, 13 and 19 being the check plots. Beginning in 1941, an application of ground limestone at the rate of one ton per acre has been made to a 20-foot strip along the north end of the plots once every three years before the potato crop in every case. Beginning in 1945, the manure and fertilizers were applied at double the usual rate to a 20-foot strip along the south end of the plots.

With the design of the experiment as outlined above, it was possible to make the following comparisons: (1) the effect of growing potatoes continuously with growing them in rotation; (2) the effect of manure alone with fertilizers alone and with manure and fertilizers in combination; (3) the effect of $NaNO_3$ with $(NH_4)_2SO_4$ as a source of nitrogen; (4) the effect of application of ground limestone with no limestone; (5) the effect of different rates of application of the manure and fertilizers.

YIELDS

Average yields of potatoes for the period 1927 to 1948 are presented in Table 1 to compare the effect of potatoes grown continuously with that of potatoes grown in rotation under the different manure and fertilizer treatments. From these data, the following observations can be made: *(a)* The yields with each treatment were always higher where the potatoes were grown in rotation. *(b)* There was a larger percentage of marketable potatoes when grown in rotation on the check and NPK plots; where manure was used, this difference was slight. *(c)* The largest yields were obtained on the manured plots. *(d)* The yields were larger where manure alone was used than where half manure and half fertilizer was employed. *(e)* Larger yields were obtained where $NaNO_3$ was used than where $(NH_4)_2SO_4$ was the source of nitrogen; this difference was greater where these materials were used without manure.

TABLE 2.—COMPARISON OF YIELDS OF POTATOES GROWN CONTINUOUSLY WITH YIELDS OF POTATOES GROWN IN ROTATION UNDER DIFFERENT FERTILIZER TREATMENTS AND ON LIMED AND UNLIMED AREAS

(Average for 8 years—1941–48 inclusive—in bu./ac.)

Treatment	Continuously		In rotation	
	Unlimed	Limed	Unlimed	Limed
1. Check	49	76	111	138
2. Manure	239	262	268	292
3. NPK ($NaNO_3$)	135	162	224	247
4. NPK ($(NH_4)_2SO_4$)	41	133	168	235
5. ½ Manure ½ NPK ($NaNO_3$)	230	236	250	265
6. ½ Manure ½ NPK ($(NH_4)_2SO_4$)	232	256	244	273

TABLE 3.—COMPARISON OF YIELDS OF POTATOES GROWN CONTINUOUSLY WITH YIELDS OF POTATOES GROWN IN ROTATION UNDER DIFFERENT FERTILIZER TREATMENTS AND ON AREAS RECEIVING SINGLE AND DOUBLE APPLICATIONS OF THE TREATMENTS

(Average for 4 years—1945–48 inclusive—in bu./ac.)

Treatment	Continuously		In rotation	
	Single	Double	Single	Double
1. Check	59	75	128	160
2. Manure	275	357	329	392
3. NPK ($NaNO_3$)	121	225	263	343
4. NPK ($(NH_4)_2SO_4$)	29	41	194	223
5. ½ Manure ½ NPK ($NaNO_3$)	256	368	283	379
6. ½ Manure ½ NPK ($(NH_4)_2SO_4$)	252	357	289	370

Average results for the period 1941 to 1948 are presented in Table 2 to show the comparison of yields of potatoes grown continuously with those of potatoes grown in rotation under the different manure and fertilizer treatments and on limed and unlimed areas. These cover the period during which lime was applied to a part of the experimental area. The data show that, for this 8-year period, as for the 22-year period presented in Table 1, yields were higher where the potatoes were grown in rotation and the largest yields were obtained on the manured plots. In each case, yields were higher on the limed plots. The greatest increase due to the lime was on the plot receiving sulphate of ammonia without manure on the continuous potatoes block. Here the average yield of the unlimed plot was less than that of the unlimed check plot.

Average results for the period 1945–1948 are presented in Table 3 to show the comparison of yields of potatoes grown continuously with those of potatoes grown in rotation under the different manure and fertilizer treatments and on areas receiving single and double applications of the treatments. As in the previous comparisons the yields were larger where potatoes were grown in rotation and the largest yields were obtained where manure was applied. Where potatoes were grown continuously, the yields

TABLE 4.—AVERAGE YIELDS OF BARLEY UNDER VARIOUS TREATMENTS AND FOR DIFFERENT PERIODS
(Bushels per acre)

Treatment	1937–48	1942–48		1946–48	
	Unlimed single	Unlimed single	Limed single	Unlimed single	Unlimed double
1. Check	14	11	17	6	4
2. Manure	26	20	27	14	15
3. NPK ($NaNO_3$)	17	14	21	9	9
4. NPK ($(NH_4)_2SO_4$)	10	4	12	3	1
5. ½ Manure ½ NPK ($NaNO_3$)	21	17	25	15	13
6. {½ Manure ½ NPK ($(NH_4)_2SO_4$)	21	18	26	14	13

TABLE 5.—AVERAGE YIELDS OF CLOVER UNDER VARIOUS TREATMENTS AND FOR DIFFERENT PERIODS
(Tons per acre)

Treatment	1937–48	1942–48		1947–48	
	Unlimed single	Unlimed single	Limed single	Unlimed single	Unlimed Double
1. Check	0.72	0.64	1.25	0.80	0.67
2. Manure	1.70	1.48	2.68	1.52	2.15
3. NPK ($NaNO_3$)	0.74	0.64	1.85	0.91	0.85
4. NPK ($(NH_4)_2SO_4$)	0.46	0.33	1.82	0.00	0.00
5. ½ Manure ½ NPK ($NaNO_3$)	1.39	1.17	1.76	1.19	1.87
6. {½ Manure ½ NPK ($(NH_4)_2SO_4$)	1.29	1.05	2.17	1.11	1.72

from the plots receiving NPK with the nitrogen supplied by sulphate of ammonia were lower than on the untreated plots. In every case, yields were increased by the double treatment.

The average yields of barley under the different manure and fertilizer treatments comparing limed and unlimed areas and comparing areas receiving single with those receiving double applications of the treatments are presented in Table 4. In every case, the manure treatments gave the highest yield. The lowest yields were obtained where sulphate of ammonia was used without manure. In comparing limed with unlimed areas, the yields were higher on the limed plots. In comparing the effects of single and double treatments, average yields were usually slightly lower on the double treatments. Here it might be noted that the treatments were applied to the potato crop the year previous to the barley crop and resulted in larger yields of potatoes.

The average yields of clover under the different manure and fertilizer treatments, comparing limed and unlimed areas and comparing areas receiving single and those receiving double applications of the treatments are presented in Table 5. In all but one case (treatment 5, limed) yields were highest where manure was applied. Except where lime was used, yields were lowest on treatment number 4 where sulphate of ammonia

was used without manure. In 1947 and 1948, no yields were reported on this treatment. Yields were considerably higher on the limed than on the unlimed treatments, the greatest increase occurring on treatment number 4. When the yields for the double treatment are compared with those from the single treatment, it is seen that the double treatment increased yields wherever manure was applied but not where manure was omitted.

SOIL COMPOSITION

Soil samples were collected from each section of all plots in the fall of 1948 and examined in the laboratory. In Table 6, the average results for reaction (pH), loss on ignition and nitrogen for the plots receiving the different manure and fertilizer treatments are presented. Since lime was added to certain of these plots and might be expected to affect the pH values, it was thought to be of interest to show, as well, the average pH values for the unlimed plots only. The average pH values ranged from 4.7 on the plots receiving sulphate of ammonia without manure to 5.5 on the plots receiving manure alone. Considering the unlimed plots only, these values were 4.3 and 5.3 respectively. It is evident that manure has increased, and sulphate of ammonia has decreased, pH values. Organic matter as measured by loss on ignition and nitrogen was highest on those plots to which manure had been applied and lowest average values were found on the check plots.

In Table 7, the average results of the same determinations for all plots receiving lime since 1941 are compared with those for plots receiving the

TABLE 6.—AVERAGE RESULTS OF ANALYSIS OF SOIL SAMPLES FROM THE PLOTS RECEIVING DIFFERENT MANURE AND FERTILIZER TREATMENTS

(Reaction, Loss on Ignition, Nitrogen)

Treatment	pH		L. on I. %	N %
	All plots	Unlimed plots		
1. Check	5.2	4.9	3.94	0.15
2. Manure	5.5	5.3	4.82	0.18
3. NPK ($NaNO_3$)	5.0	4.7	4.19	0.16
4. NPK ($(NH_4)_2SO_4$)	4.7	4.3	4.22	0.16
5. ½ Manure ½ NPK ($NaNO_3$)	5.3	5.0	4.81	0.18
6. {½ Manure ½ NPK ($(NH_4)_2SO_4$)	5.3	5.0	4.67	0.18

TABLE 7.—AVERAGE RESULTS OF ANALYSIS OF SOIL SAMPLES FROM LIMED, UNLIMED AND DOUBLE TREATMENT PLOTS

(Reaction, Loss on Ignition, Nitrogen)

Description	pH	L. on I. %	N %
Limed	5.7	4.45	0.17
Unlimed	4.9	4.39	0.16
Double treatment	4.8	4.49	0.17

Table 8.—Average results of analysis of soil samples from the block in potatoes continuously and the three blocks in crop rotation

(Reaction, Loss on Ignition, Nitrogen)

Description	pH		L. on I. %	N %
	All plots	Unlimed plots		
Continuous	5.3	5.0	4.09	0.15
Rotation				
Potatoes, 1948	5.0	4.9	4.33	0.16
Grain, 1948	5.1	4.8	4.64	0.17
Hay, 1948	5.2	4.8	4.71	0.18

Table 9.—Average results of analysis of soil samples from the plots receiving different manure and fertilizer treatments

(Soluble phosphorus and exchangeable bases)

Treatment	Sol. P		Ex. CaO		Ex. MgO %	Ex. K_2O %
	All plots p.p.m.P	Unlimed plots p.p.m.P	All plots %	Unlimed plots %		
1. Check	15	13	0.103	0.061	0.004	0.007
2. Manure	44	37	0.145	0.104	0.009	0.010
3. NPK ($NaNO_3$)	37	32	0.109	0.067	0.003	0.008
4. NPK ($(NH_4)_2SO_4$)	37	36	0.091	0.047	0.002	0.008
5. {½ Manure, ½ NPK ($NaNO_3$)	51	44	0.147	0.107	0.007	0.010
6. {½ Manure, ½ NPK ($(NH_4)_2SO_4$)	51	47	0.138	0.089	0.006	0.009

normal treatment from the beginning of the experiment in 1927 and with those for plots receiving the double manure and fertilizer treatments since 1945. The samples from the plots which have received lime showed increased pH values. There appeared to be no significant differences in the results for loss on ignition and nitrogen due to these treatments.

In Table 8, the average results of the same determinations for all the plots on which potatoes have been grown continuously are presented in comparison with similar results for each block of plots on which the three-year rotation has been followed. The average pH values on the three blocks in the rotation were lower than that for the block continuously in potatoes but when the results for the unlimed plots alone are considered, the differences were small and probably not significant. The figures for loss on ignition and nitrogen indicate that the organic matter levels were slightly lower on the plots which were cultivated every year for potatoes.

In Table 9, the average results for readily soluble phosphorus and the exchangeable bases for the plots receiving the different manure and fertilizer treatments are presented. Since lime where applied affected the soluble phosphorus and exchangeable calcium contents (Table 10), average values

TABLE 10.—AVERAGE RESULTS OF ANALYSIS OF SOIL SAMPLES FROM LIMED AND UNLIMED PLOTS

(Soluble phosphorus and exchangeable bases)

Description	Sol. P. p.p.m. P	Ex. CaO %	Ex. MgO %	Ex. K_2O %
Limed	44	0.165	0.006	0.009
Unlimed	34	0.079	0.005	0.008

TABLE 11.—AVERAGE RESULTS OF ANALYSIS OF SOIL SAMPLES FROM THE BLOCK IN POTATOES CONTINUOUSLY AND THE THREE BLOCKS IN CROP ROTATION

(Soluble phosphorus and exchangeable bases)

Description	Sol. P		Ex. CaO		Ex. MgO %	Ex. K_2O %
	All plots p.p.m.P	Unlimed plots p.p.m.P	All plots %	Unlimed plots %		
Continuous	79	66	0.132	0.097	0.007	0.015
Rotation						
Potatoes, 1948	27	26	0.084	0.068	0.006	0.007
Grain, 1948	25	23	0.120	0.070	0.003	0.007
Hay, 1948	27	24	0.152	0.082	0.005	0.005

for these determinations on unlimed plots only are also presented. The phosphorus determined was that soluble in ammonium sulphate solution at pH 3·0 (modified Truog method) and it is apparent that the amounts present have been influenced by the treatments. Considering average values for all (limed and unlimed) plots, the lowest results (15 p.p.m. P) were found on the untreated plots. Applications of manure alone increased the readily soluble phosphorus considerably (to 44 p.p.m. P) as did those of inorganic phosphorus (treatments 3 and 4) though to a slightly less extent (37 p.p.m. P). Highest values for soluble phosphorus (51 p.p.m. P) were obtained on those plots where part of the added phosphorus came from manure and part from an inorganic source. The same picture is shown when only the unlimed plots are considered.

The effect of manure on the exchangeable base content of the soil samples was also quite pronounced. The figures in Table 9 show that highest average values for calcium (all plots), magnesium and potassium were found where manure was applied. The effect of the manure applications on potassium was not great, however. There is frequently a close relationship between the pH values of soils and their exchangeable lime content and this observation was true for the samples under consideration. Reference to Table 6 shows that the highest pH values were obtained on the plots receiving manure. The same relationship was found when the results for the unlimed plots were considered separately. The pH values

and exchangeable calcium contents of the samples were increased where manure was applied. The effect of sulphate of ammonia in reducing the exchangeable calcium on unlimed plots was quite pronounced.

In Table 10 the average results of the same determinations for all plots receiving lime since 1941 are compared with those for plots receiving the normal treatment from the beginning of the experiment in 1927. (These determinations were not made on the samples from the plots receiving the double manure and fertilizer treatments since 1945). It is apparent that liming has increased the readily soluble phosphorus content of these samples. It is usually assumed that the liming of acid soils reduces the ability of iron and aluminum to fix phosphorus in a relatively insoluble form and this assumption has been supported by these results. As was to be expected, the applications of limestone greatly increased the exchangeable calcium content but did not affect the exchangeable magnesium and potassium.

In Table 11, the average results of the same determinations for all the plots on which potatoes have been grown continuously are presented in comparison with similar results for each block of plots on which the three-year rotation has been followed. As in Table 9, the average results for soluble phosphorus and exchangeable calcium on the unlimed plots are shown in separate columns. The average soluble phosphorus content and the average exchangeable potassium content of the plots which have been continuously in potatoes are very much higher than those for the three blocks in rotation. This is no doubt due to the fact that these elements were applied in the fertilizer each year where potatoes were grown continuously but only once every three years to the potato crop in the rotation. There was some variation between blocks in the values found for exchangeable calcium and magnesium. For the unlimed plots, the exchangeable calcium content was very low in each case and the differences were probably not significant.

DISCUSSION OF RESULTS

Although the experiment was not laid out in such a way that the results could be analysed statistically, results obtained over a period of 22 years should give a definite indication of results that can be expected under comparable conditions. It seems to be clearly indicated that the yields of potatoes when grown continuously were less than when grown in rotation. The beneficial effect of applications of manure were quite apparent and the experimental results show that, in nearly every case, a manure treatment alone gave higher yields than where the application was half manure and half commercial fertilizers. The use of nitrate of soda as a source of nitrogen was preferable to sulphate of ammonia, particularly when no manure was used. In many cases, yields on the sulphate of ammonia plots without manure were lower than on the untreated plots. Liming increased the yields of all crops and gave the greatest increases where sulphate of ammonia without manure had been applied over the 14-year period before liming was started. During the last few years when a double application of manure and fertilizer has been made to part of the plots, the results indicate that the yields of potatoes were increased and the yields of clover were improved on all plots where manure was applied, but yields

of barley were not increased. However, the length of time that the double treatment has been used has been too short for any general conclusion to be reached.

The results of the determinations made on the soil samples have indicated that the applications of manure have increased the organic matter levels, the readily soluble phosphorus and the exchangeable base content. Applications of sulphate of ammonia over a long period reduced the soil reaction and exchangeable calcium. The pH values were increased on all plots where lime was applied, as were those for exchangeable calcium and readily soluble phosphorus. There is an indication that continuous cropping has reduced the organic matter below that found where the rotation was followed. Levels of soluble phosphorus and exchangeable potassium were considerably higher on the plots continuously cropped to potatoes, probably due to the more frequent application of fertilizers.

CONCLUSIONS

General conclusions from this experiment are: (1) that better yields of potatoes can be obtained when this crop is grown in rotation; (2) that manure is extremely beneficial on this soil; (3) that nitrate of soda is preferable to sulphate of ammonia as a source of nitrogen on this soil; and (4) that the use of ground limestone is beneficial.

STUDIES OF THE COMPOSITION OF DECIDUOUS FOREST TREE LEAVES BEFORE AND AFTER PARTIAL DECOMPOSITION[1]

B. B. COLDWELL[2] AND W. A. DELONG[3]

Department of Chemistry, Macdonald College, Que.

[Received for publication July 27, 1950]

INTRODUCTION

Podsol soils have been intensively studied ever since the pioneer researches of Dokuchaev (9), yet the mechanism of their development is still obscure. It is generally assumed that acidic substances are responsible for the transport of bases during podsolization and many of the earlier investigators (9) stressed the importance of organic acids in this process. However, the only evidence supporting this idea was the presence of an acidic A_0 layer, as organic acids were not isolated from soil until 1913 (26). Uronic carboxyl groups have also been proposed as the agents involved in podsolization (19).

In view of the importance of podsol soils in Eastern Canada (29) an investigation of the fundamental processes responsible for their development was started at Macdonald College in 1947. The problem is being approached through a study of the acidic components leached by natural rainfall from decomposing leaves of deciduous forest trees. In connection with this work it was important to know the annual leaf-fall of the different species of trees and the nature and extent of decomposition of the leaves during weathering. These studies are described in the following sections of this paper.

EXPERIMENTAL PROCEDURE

Selection and Preparation of Sampling Areas

In September, 1947, sites were selected in the Morgan Arboretum at Macdonald College for the purpose of collecting and measuring the autumn leaf-fall of the following species of trees: American beech (*Fagus grandifolia* Ehrh.); gray birch (*Betula populifolia* Marsh.); sugar maple (*Acer saccharum* Marsh.) and poplar (*Populus grandidentata* Michx. and *P. tremuloides* Michx.).

The beech and maple stands are mature, quite dense and free of other species, situated on deep sand and glacial till, respectively. The birch areas were located in a relatively open pasture on a mixed sand and clay formation in 1947 and 1948. New sites were selected in 1949 under more dense growth on deep sand. In 1947, the poplar leaf-fall was a mixture of nearly one-third *P. tremuloides* and two-thirds *P. grandidentata*. The stand was thin and mixed with birch, maple and evergreens. New sites were selected in 1948 under a thin, mature stand of *P. grandidentata* located on imperfectly drained sand.

All undergrowth and loose, partly decomposed litter were removed from the selected areas which were then enclosed with rot-proofed canvas windscreens. Several sites were prepared under each species. The total area enclosed by windscreens was nearly 400 sq. ft. under beech and poplar, 500 sq. ft. under maple and 750 sq. ft. under birch.

---

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., and the Dominion Experimental Farms Service. Macdonald College Journal Series No. 268.
[2] Lecturer in Chemistry.
[3] Associate Professor of Chemistry.

Collection of Leaf-litter

The leaves falling within the enclosed areas were collected at frequent intervals during the period of leaf-fall. Beech, maple and poplar leaves were picked up by hand. The birch leaves, collected with a hand-rake, were contaminated with a small amount of grass. Leaves of other species falling inside the screened areas were discarded. In 1947, eleven collections were made between October 9 and November 4 when leaf-fall was complete. Only in one or two instances were the fallen leaves exposed to rain before being collected. Collections were made from September 29 to November 11 in 1948. The weather was less favourable than during the previous season and an estimated 50 per cent of the leaf-litter was leached to some extent by rain before harvesting. In 1949, leaf collection began on October 1 and was completed on November 6. Only the last collection was severely leached before harvest.

The leaves of each species were put in separate bags as collected and stored in a small building in the arboretum. When leaf-fall was finished, each species was thoroughly mixed and weighed. Known quantities were exposed to weathering as described in the following section and the remainder taken to the laboratory for analysis.

Methods of Weathering Leaves

The leaves collected in 1947 were exposed to decomposition by rain and microorganisms under two different conditions.

A known quantity of leaves of each species was placed on 1/8-in. mesh wire screens, supported on trays specially designed to collect the natural rainfall percolating through the layer of leaves. Each tray was 4 ft. × 3 ft. × 10 in. with a bottom sloping towards the centre and front terminating in a pipe connected to a covered pail. The trays were set into the ground with the top about one inch above ground level. A trench was dug the required depth to hold the pails for collecting the leachates resulting from natural rainfall. Each tray was covered with 1/4-in. mesh wire screens to exclude small animals, wind-blown leaves, etc. All surfaces of screens, trays and pails were treated with asphalt paint to inhibit corrosion. The leaves were exposed in the trays for 11 months.

To compare the degree of decomposition of leaves in trays with that of leaves lying over soil, a known amount of each species was exposed to weathering for 10 months on 1/8-in. mesh wire screens (4 ft. × 3 ft.) in contact with the ground and held in place by canvas windscreens. These were located on a single soil type in the vicinity of the trays.

METHODS OF ANALYSIS

Analysis of Leaf Material

Samples of the freshly fallen leaves and the residues from the trays and ground-screens were air-dried in the laboratory, weighed, thoroughly mixed and a representative portion of each ground in a Wiley Mill so that all of the material would pass through a 20-mesh sieve. The chemical determinations were made on representative sub-samples of this ground material.

Moisture was calculated as the loss in weight when two-gram samples were dried to constant weight in an electric oven at 105° C.

Ash was found by igniting weighed samples in porcelain crucibles in a muffle at 600° C.

Total nitrogen was determined by the micro-Kjeldahl method (20).

Lignin determinations were made by the 72 per cent sulphuric acid method as described by Ritter and co-workers (25), after removal of extractives and pretreating with one per cent hydrochloric acid.

"Extractive-free" material for subsequent holocellulose determinations was prepared by a modification of the procedure employed for wood (30). Weighed samples of ground leaf material were transferred to fritted glass extraction thimbles (C porosity) and extracted in a Soxhlet for 16 hours with alcohol-benzene solution (32 parts by weight of alcohol and 68 parts by weight of benzene). The residue was washed several times with alcohol on a Buchner, using light suction, and allowed to air-dry until free of alcohol. It was then refluxed for three hours with distilled water (150 ml./g.), filtered, washed several times with hot water, and air-dried. Quantitative estimation of the alcohol-benzene and hot water soluble material was obtained using five-gram samples. Large batches of "extractive-free" material were prepared using 15-g. samples for the first extraction and combining the contents of two thimbles for the boiling water digestion. Any sand contaminating the leaf material remained in the digestion flask when the extracted residue was carefully transferred to a Buchner by successive washings with hot distilled water. It was collected in a tared Gooch crucible, ignited at 600° C. and weighed. The mean of six 30-g. samples was calculated as per cent sand. All results in this paper are reported on the basis of the sand-free materials.

The "extractive-free" material was used for the determination of holocellulose, employing the acid chlorite method of Wise, Murphy and D'Addieco (35).

Alpha cellulose was determined as described by Ritter (24) on samples of air-dried holocellulose.

Analysis of Leachates

The leachates were collected from the trays at each rainfall during the period of weathering except for the winter months. They were filtered to remove any suspended matter and the volumes recorded. Titratable acidity or alkalinity was determined by titrating a suitable aliquot to pH 7 with 0.01 N hydrochloric acid or sodium hydroxide; pH was measured with a potentiometer using a glass electrode. Non-volatile solids and ash were found by the methods used for potable water (20). Ash alkalinity was determined by the method described by Purves (22).

RESULTS AND DISCUSSION

The Amount of Leaf-Fall from Hardwoods

The leaf-fall of beech, birch, maple and poplar trees was measured for three successive years. The results are given in Table I.

The yield was highest from maple followed by beech, birch and poplar. The leaf-fall varies considerably from year to year, particularly under birch and poplar, indicating these two species may be more susceptible to variations in climatic conditions than maple and beech.

TABLE 1.—ANNUAL LEAF-FALL OF FOUR SPECIES OF DECIDUOUS FOREST TREES

(Values represent pounds of dry matter per acre)

Species	1947	1948	1949	Average
Maple	2690	3116	3225	3010
Beech	1689	2096	2043	1943
Birch	1136	2341	1032	1503
Poplar	1421*	2044	1002	1489

* Mixture of *P. grandidentata* and *P. tremuloides*.

Except for maple, the leaf-fall in the Morgan Arboretum appears to be less abundant than in New York State. Chandler (5) found the fall of hardwood leaf litter ranged from 2425–3020 lb. of dry matter per acre on several soil types in 1940. The average fall of litter from conifers is of the same magnitude as from hardwoods. Thus a mixed stand of white and Norway pine in southern New England gave an annual yield of 2000–3000 lb. of litter per acre (17).

According to Lutz and Chandler (11) tree leaves are the largest single source of forest soil organic matter. Watson (34) quotes Ebermayer who found the annual leaf-fall in a mature beech forest nearly equivalent to the fall of wood.

The Composition of Freshly Fallen Leaves

The mineral composition of forest litter has received considerable attention (2, 5, 6, 10, 14, 16, 28), but there is little information available regarding the organic composition of leaves of different forest trees. In Table 2 are recorded the analyses of freshly fallen leaves collected in 1947.

Maple leaves have the highest ash content of the four species. Lutz and Chandler (11) give the average ash content of maple leaves as 11.85 per cent. Of the common hardwoods, maple leaves generally have the highest ash content. Melin (15) found the ash content of beech leaves to be

TABLE 2.—THE COMPOSITION OF MATURE LEAVES FROM FOUR SPECIES OF DECIDUOUS TREES

(Values represent percentages based on dry matter)

Fraction	Beech	Birch	Maple	Poplar*
Ash	9.44	7.21	12.33	9.41
Nitrogen	0.81	1.12	0.83	0.84
Alcohol-benzene soluble	16.18	18.30	20.42	19.54
Hot water soluble	13.63	21.48	23.68	22.03
Apparent lignin, ash free	24.03	21.87	15.49	20.00
Holocellulose	35.15	24.89	26.82	27.09
Alpha cellulose			18.06	18.91
Hemicellulose, crude			8.76	8.18

* Mixture of *P. grandidentata* and *P. tremuloides*.

9.36 per cent although the average of several reported values is 7.37 per cent (11). Leaves of *P. grandidentata* and *P. populifolia* had ash contents of 3.85 and 4.07 per cent, respectively (15). Numerous investigations have shown that the ash content of forest tree leaves may vary considerably according to species, age of the leaves and composition of the soil.

The nitrogen contents of the leaves as found in the present study are in general agreement with those reported in the literature (11, 5, 10).

Melin (15) determined the proximate composition of several species of mature freshly fallen leaves using Waksman's modified method (31, III). Three of the species, beech, maple and poplar were used in the present study and although different analytical methods were employed it is of interest to compare the results. Reasonably good agreement was obtained for the carbohydrate and lignin fractions, except for the lignin content of poplar leaves. Melin (15) reports a value of 32.69 per cent as compared to 20.00 per cent found in the present study. A higher content of water soluble material and substances soluble in organic solvents was found in the present work as compared to those found by Melin, except for the water soluble content of maple leaves which agrees fairly well. The differences in the analyses may be partly due to the fact that the leaves analysed by Melin were not representative of the total leaf-fall. In both studies, the species appear in the same order with regard to content of "extractives", i.e., maple, poplar and beech.

Decomposition of Freshly Fallen Leaves

Visual observations during the summer of 1948 indicated that maple and birch leaves decomposed more rapidly than those of poplar and beech. These observations are confirmed by the data given in Table 3 for leaves collected in the autum of 1947.

Birch and maple leaves decomposed nearly the same amount on the trays and over the soil. Beech and poplar leaves weathered more extensively in contact with the soil than in the trays.

The above experiment was repeated using leaf-litter collected during the autumn of 1948 and exposing an amount of each species equivalent to 10 times the fresh weight collected per 12 sq. ft. of ground surface. The

Table 3.—Loss in weight of leaves exposed to weathering in trays and in contact with the soil

(Basis: 100 g. oven-dry unweathered leaves)

Species	Trays*		Soil*	
	Original weight (g)	Loss (%)	Original weight (g)	Loss (%)
Beech	3218	18.2	7012	30.3
Birch	6022	38.2	8184	41.6
Maple	3581	42.7	7209	41.0
Poplar†	2996	24.5	5519	35.1

* After 11 months on trays and 10 months over soil, respectively.
† Mixture of *P. grandidentata and P. tremuloides.*

amounts exposed in the trays and in contact with the soil ranged from 2560 g. of poplar to 3899 g. of maple leaves. Under these conditions decomposition in every case was considerably greater in the trays than over soil, although less than the previous year. In both experiments the loss in weight was nearly the same for maple and birch, less for poplar, and beech leaves were most resistant to decomposition.

It was noted that the leaves exposed in the trays and on the ground in 1949 dried out more rapidly following a rain than in 1948, presumably because of the larger quantity of leaves on the screens in 1948. Also, the tray residues contained more moisture than the ground residues when sampled in September, 1949, the soil apparently acting like a blotter. The total precipitation from April to September at Macdonald College was four inches higher in 1949 than in the previous year; however all of this excess fell in April and September. Precipitation during the summer months was very nearly the same in both years. Bartholomew and Norman (3), and Waksman and Purvis (33) have emphasized the importance of moisture in the microbiological decomposition of organic materials. In the present study, it appears that the rate of decomposition is markedly influenced by the moisture content which in turn is affected by the quantity of material, the conditions of exposure and climatic conditions.

It is interesting to compare these results with those obtained by other workers. Lunt (10) obtained losses of 2.7 and 7.0 per cent respectively, on exposing mature beech and maple leaves to natural weathering for seven weeks. Gustafson (8) found that freshly fallen maple leaves lost 30 per cent of their dry matter during exposure on the ground in a mixed stand of hardwoods for one year. Melin (15), and Broadfoot and Pierre (4) studied the decomposition of various species of forest leaves under controlled conditions in the laboratory. Beech leaves were most resistant to decomposition, birch was readily attacked, while maple and poplar were intermediate. The agreement between the results of these investigators and those obtained in the present study is significant, particularly when it is considered that the conditions were quite different in the various investigations.

Changes in the Composition of Leaves during Weathering

The decomposition of plant materials is influenced by many factors, such as the nature of the fresh material, the environmental conditions and the microorganisms and fauna concerned. Many investigators (12, 13, 15, 18, 23, 31, 34), have shown that there is a rapid loss of water soluble substances such as sugars, starches, and nitrogenous compounds in the initial stages of decomposition. The components of the cell wall are attacked less rapidly. Cellulose may disappear completely after a period of time, but lignin is relatively resistant to microbiological attack.

The general group of hemicelluloses appear to be attacked fairly rapidly, particularly in the early stages of decomposition. However, it must be emphasized that these conclusions are based mainly on results obtained by the proximate analysis of plant materials and soil. This method of study does not distinguish between living and dead organic matter or between plant remains and organic matter of microbial origin. Over 30 per cent of

the organic matter in fertile soils may be microorganic, consisting of nitrogenous compounds, humus-like substances and complex carbohydrates (7). Thus it is evident that the method of proximate analysis provides a very incomplete picture of the changes which take place in decomposing organic matter.

The composition of the partially decomposed tray residues, resulting from the weathering of leaves collected in 1947, is given in Table 4. Changes in composition, calculated as percentages of the amounts of the different fractions present in 100 g. of oven-dry original leaves (see Table 2), are recorded in Table 5.

The greatest losses have occurred in the alcohol-benzene soluble, hot water soluble, ash and holocellulose fractions of all species. The decrease in the holocellulose fraction of poplar appears to be due almost entirely to loss of alpha cellulose. The crude hemicellulose (holocellulose-alpha cellulose) content of partially decomposed poplar leaves is only slightly less than in the unweathered leaves (see Tables 2 and 4). The loss of hemicelluloses was probably more extensive than indicated by the data since the yield of holocellulose was always less than the theoretical quantity, pre-

Table 4.—The composition of leaves collected in 1947 after eleven months weathering in trays

(Basis: 100 g. of oven-dry unweathered leaves)

Fraction	Beech	Birch	Maple	Poplar
Ash	7.50	3.47	5.52	6.72
Nitrogen	0.92	1.18	0.69	0.79
Alcohol-benzene soluble	7.00	6.91	5.82	8.95
Hot water soluble	7.33	6.16	10.41	7.12
Apparent lignin, ash free	25.72	24.32	13.57	27.92
Holocellulose	28.58	12.44	15.40	17.46
Alpha cellulose	—	—	8.95	9.38
Hemicellulose, crude	—	—	6.45	0.08

Table 5.—Percentage change in the composition of leaves during weathering

(Basis: 100 g. of oven-dry unweathered leaves)

Fraction	Beech	Birch	Maple	Poplar
Ash	−20.5	−51.8	−55.2	−28.5
Nitrogen	+12.3	+ 5.3	−16.8	− 5.9
Alcohol-benzene soluble	−56.7	−62.2	−71.4	−54.1
Hot water soluble	−46.2	−71.3	−56.1	−67.6
Apparent lignin, ash free	+ 7.1	+10.1	−12.3	+39.6
Holocellulose	−18.6	−50.0	−42.5	−35.5
Alpha cellulose	—	—	−50.4	−50.3
Hemicellulose, crude	—	—	−26.3	− 1.2

sumably due to hydrolysis of some of the hemicelluloses during acid chlorite digestion. Adams and Castagne (1) obtained evidence of hydrolysis of hemicelluloses when preparing holocellulose samples of cereal straws. Similar results were experienced in the preparation of wood holocellulose (36). The theoretical holocellulose content of a plant material is obtained by subtracting from 100, the sum of the percentages of ash, lignin and protein ($N \times 6.25$) in the oven-dry extractive-free material. The percentage holocellulose in the unextracted original tissue may then be calculated using a factor determined by the analytical results.

The increase in the apparent lignin content of poplar leaves, and to a less extent in birch and beech, as a result of decomposition emphasizes the inadequacy of the method of determining lignin. Waksman (32) cites several papers which suggest that lignin is decomposed to some extent by certain microorganisms. On the other hand there is evidence that certain dark-colored filamentous fungi, commonly inhabiting soil and decaying plant material, may contain substances insoluble in 72 per cent sulphuric acid (21). The actual structure of lignin is unknown and as pointed out by Norman (19), there may be many lignins just as there are many proteins. Thus, it is quite evident that insolubility in 72 per cent sulphuric acid is a very empirical measure of lignin, especially in a complex system such as decomposing organic matter.

The composition of a plant material is one of several factors which influence the rate of decomposition. In general, a low content of water soluble substances and nitrogen, accompanied by a relatively high amount of lignin is conducive to slow decomposition (31, 32). Thus the slow rate of decomposition of beech leaves as compared to that of maple would be expected on the basis of their composition (see Table 2). Birch leaves contained more nitrogen than poplar which likely influenced the rate of decomposition of the former.

Characteristics of Leachates

The characteristics of the natural rainwater leachates obtained from the trays during eleven months' exposure of leaves collected in the autumn of 1947 are summarized in Table 6.

TABLE 6.—CHARACTERISTICS OF LEACHATES FROM LEAVES DECOMPOSING ON TRAYS DURING 1947–48

(Basis: Total volume of leachates collected)

Analysis	Beech	Birch	Maple	Poplar
Non-volatile solids (g.)	66.0	257.4	204.5	118.1
Ash (g.)	27.7	85.9	41.5	32.4
Titratable acidity (m.e.)	53.5	−24.7	261.7	50.8
Ash alkalinity (m.e.)	150.4	927.9	493.7	318.8
Total acidity (m.e.)	203.9	903.2	755.4	369.6
Ash alkalinity/ash	5	11	12	10

The amount of non-volatile solids and ash removed by leaching was greatest from birch, followed by maple, poplar and beech. The degree of decomposition based on loss in weight followed nearly the same order of species (see Table 3). Maple leachates had the highest titratable acidity, followed in descending order by beech, poplar and birch. Assuming that the bases were neutralizing acids, the total acidity was calculated by adding together the values for titratable acidity and ash alkalinity. Birch and maple leachates have high total acidities compared to those of poplar and beech.

The leachates of each species became progressively more alkaline with time. This is in agreement with the findings of Stepanov (27). Maple leachate was consistently the most acidic, with a minimum pH of 4.4 and a maximum of 6.5. Birch leachates collected in the late fall and early spring were acidic, but the pH increased to 7.0 by May 1 and remained alkaline throughout the season, reaching a maximum value of 7.7. Beech and poplar leachates had pH values between 5.5 and 5.8 in the fall, increasing during the following summer to neutrality or slight alkalinity. Poplar leachates were slightly less acidic than beech in most cases.

The above results were confirmed by the analysis of leachates obtained during 1948–49, from trays containing leaves collected in the fall of 1948 (see p. 460). The results appear in Table 7.

Table 7.—Characteristics of leachates from leaves decomposing on trays during 1948–49

(Basis: total volume of leachates collected)

Analysis	Beech	Birch	Maple	Poplar
Non-volatile solids (g.)	48.6	87.0	270.6	82.6
Ash (g.)	16.8	22.7	65.4	29.2
Titratable acidity (m.e.)	21.6	−7.9	261.5	−15.4
Ash alkalinity (m.e.)	114.9	290.0	632.3	302.0
Total acidity (m.e.)	136.5	282.1	893.8	286.6
Ash alkalinity/ash	6	13	10	10

There are some differences apparently due to the amount of leaves exposed to weathering. The low content of solids in the birch leachates is surprising, particularly as the degree of decomposition of birch and maple leaves was nearly the same, 27.5 and 27.2 per cent respectively. The value obtained for alkalinity of ash may vary as a result of several factors, such as the ratio of monovalent to divalent cations and the proportion of basic to acidic oxides in the ash. However, the relative constancy of the ratio of ash alkalinity to ash for all species in both experiments suggests little change in the composition of the ash of the leaves in the two successive years. Further, the ash composition of birch, maple and poplar leachates may be essentially the same.

SUMMARY

The leaf-fall of four species of deciduous forest trees was determined for three successive years. The average yearly leaf-fall of each species in pounds of dry matter per acre was as follows: maple—3010; beech—1943; birch—1503; poplar—1489.

The proximate composition of the freshly fallen leaves of each species was determined. Maple leaves had the highest content of ash and extractives, and the lowest lignin content. Beech leaves had the lowest content of extractives and the largest amount of lignin. Birch and poplar leaves were intermediate. The holocellulose content was highest in beech leaves, followed by poplar, maple and birch.

Maple and birch leaves decomposed at twice the rate of beech leaves when exposed to weathering in trays. The differences were not so marked in the case of leaves lying in contact with the soil. Poplar leaves decomposed at an intermediate rate.

The rate of decomposition was related to leaf composition, particularly in the case of beech and maple leaves. The extent of decomposition under the conditions employed was markedly influenced by the moisture content of the decomposing material.

Ash, extractives, and alpha cellulose were quite readily removed during decomposition. Lignin and hemicelluloses were relatively resistant to decomposition. Considerable variation existed between species.

Natural rainwater leachates from maple leaves were strongly acidic throughout the season as shown by pH and titratable acidity. Leachates of birch leaves were the least acidic, while beech and poplar leachates were intermediate. In all cases the leachates became progressively more alkaline as the time and extent of decomposition increased.

ACKNOWLEDGMENTS

The authors acknowledge with gratitude their indebtedness to officers of the Experimental Farms Service, Canada Department of Agriculture, whose advice, support and assistance made this investigation possible.

The assistance of G. W. Boswall, L. E. Lutwick, W. P. McKinley and George Kay, in the field and laboratory at various times during this study, has been appreciated.

REFERENCES

1. Adams, G. A., and A. E. Castagne. Holocelluloses from straw. Can. J. Research, *B*, 26 : 325-334. 1948.
2. Alway, F. S., and R. Zon. Quantity and nutrient content of pine leaf litter. J. Forestry, 28 : 715-728. 1930.
3. Bartholomew, W. V., and A. G. Norman. The threshold moisture content for active decomposition of some mature plant materials. Proc. Soil Sci. Soc. Amer. 11 : 270-279. 1946.
4. Broadfoot, W. M., and W. H. Pierre. Forest soil studies. I. Relation of rate of decomposition of tree leaves to their acid-base balance and other chemical properties. Soil Sci. 48 : 329-348. 1939.
5. Chandler, Jr., R. F. The amount and mineral nutrient content of freshly fallen leaf litter in the hardwood forests of central New York. J. Amer. Soc. Agron. 33 : 859-871. 1941.
6. Coile, T. S. Composition of the leaf litter of forest trees. Soil Sci. 43 : 349-355. 1937.

REFERENCES—Concluded

7. Fraser, G. K. Microorganisms in relation to the production and degradation of soil organic matter. Chem. and Ind. (London) 68 : 375-377. 1949.
8. Gustafson, F. F. Decomposition of the leaves of some forest trees under field conditions. Plant Physiol. 18 : 704-707. 1943.
9. Joffe, J. S. Pedology. Rutgers University Press, New Brunswick, N.J. 1936.
10. Lunt, H. A. Effect of weathering upon dry matter and composition of hardwood leaves. J. Forestry 33 : 607-609. 1935.
11. Lutz, H. J., and R. F. Chandler, Jr. Forest soils. John Wiley and Sons, Inc., New York. 1946.
12. Marten, E. A., and G. G. Pohlman. Biological and chemical changes in the decomposition of tree litter. Proc. Soil Sci. Soc. Amer. 3 : 187. 1938.
13. Marten, E. A., and G. G. Pohlman. Forest soil studies. II. Changes in microflora and chemical composition of decomposing tree leaves. Soil Sci. 54 : 67-77. 1942.
14. McHargue, J. S., and W. R. Roy. Mineral and nitrogen content of the leaves of some forest trees at different times in the growing season. Bot. Gaz. 94 : 381-393. 1932.
15. Melin. E. Biological decomposition of some types of litter from North American forests. Ecology, 11 : 72-101. 1930.
16. Mitchell, H. L. Trends in the nitrogen, phosphorus, potassium and calcium content of the leaves of some forest trees during the growing season. Black Rock Forest Papers 16 : 30-44. 1936.
17. Morgan, M. F., and H. A. Lunt. The role of organic matter in the classification of forest soils. Jour. Amer. Soc. Agron. 24 : 655-662. 1932.
18. Norman, A. G. The biological decomposition of plant materials. II. The role of the furfuraldehyde-yielding substances in the decomposition of straws. Biochem. Jour. 23 : 1367-1384. 1929.
19. Norman, A. G. Problems in the chemistry of soil organic matter. Proc. Soil Sci. Soc. Amer. 7 : 7-15. 1942.
20. Official and tentative methods of analysis. 6th ed. Assoc. of Official Agr. Chemists. Washington. 1945.
21. Pinck, L. A., and F. E. Allison. The synthesis of lignin-like complexes by fungi. Soil Sci. 57 : 155-161. 1944.
22. Purves, C. B. *In* Cellulose and cellulose derivatives, ed. by Emil Ott. Interscience Publishers, Inc., New York. 1943.
23. Rege, R. D. Biological decomposition of cellulosic materials, with special reference to the action of fungi. Ann. Appl. Biol. 14 : 1-44. 1927.
24. Ritter, G. J. Determination of alpha-cellulose. Ind. Eng. Chem. *Anal. Ed.* 1 : 52-54. 1929.
25. Ritter, G. R., R. M. Seborg, and R. L. Mitchell. Factors affecting quantitative determination of lignin by 72 per cent sulfuric acid method. Ind. Eng. Chem. *Anal. Ed.* 4 : 202-204. 1932.
26. Shorey, E. C. Some organic soil constituents. U.S. Dept. Agr. Bur. Soils, Bull. 88. 1913.
27. Stepanov, N. N. Die zersetzung des laubabfalls der bäume und sträucher. Second Intl. Congress Soil Sci. 5, Com. 5 : 300-305. 1932.
28. Stepanov, N. N. The mineralization of foliage of forest trees and underbrush. Pedology (U.S.S.R.), No. 9 : 15-34. 1940.
29. Stobbe, P. C., and A. Leahey. Guide for the selection of agricultural soils. Dominion of Canada, Dept. of Agr., Publication 748; Farmer's Bull. 117. 1944.
30. TAPPI tentative standard T12, M-42. Oct. 22, 1942.
31. Waksman S. A., and F. G. Tenney. The composition of natural organic materials and their decomposition in the soil. I, II, III, IV, V. Soil Sci. 24 : 275-283, 317-334. 1927; 26 : 155-171. 1928; 28 : 55-84. 1929; 30 : 143-160. 1930.
32. Waksman, S. A. Principles of soil microbiology. 2nd ed. Williams and Wilkins Co., Baltimore. 1932.
33. Waksman, S. A., and E. R. Purvis. The influence of moisture upon the rapidity of decomposition of lowmoor peat. Soil Sci. 34 : 323-336. 1932.
34. Watson, C. W. Changes in composition of organic matter in process of formation of humus horizons from forest litter. Am. Soil Survey Assoc. Bull. 13 : 15-20. 1932.
35. Wise, L. E., M. Murphy, and A. A. D'Addieco. Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. Paper Trade J. 122 : No. 2, 35-43. 1946.
36. Wise, L. E. *In* Nature of the chemical components of wood. TAPPI Monograph Series, No. 6. 1948.

DIGESTIBILITY STUDIES WITH SWINE

IV. ASSOCIATIVE DIGESTIBILITY BETWEEN BARLEY AND TANKAGE[1]

C. J. WATSON[2], J. W. KENNEDY[3], W. M. DAVIDSON[3], AND E. B. FRASER[4]

[Received for publication July 27, 1950]

The Division of Animal Husbandry of the Experimental Farms Service has collaborated in the development of an Advanced Registry Feeding Ration to provide a standard ration for the testing of pigs at the various Advanced Registry Feeding Stations across Canada. It consists of the basal grains, barley, wheat and oats, plus a protein mineral supplement. The ration up to 1949 was as follows:

Basal Feed Mixtures

From 70 days to 100 lb.	Per cent	*100 lb. to 200 lb.*	Per cent
Barley	50	Barley	60
Wheat	20	Wheat	30
Oats	30	Oats	10

To this was added a protein-mineral supplement. The level of this supplement was 15 per cent of the total ration for swine of the 70 day to 100 lb. group and 6 per cent of the total ration for swine of the 100 lb. to 200 lb. group.

The protein-mineral supplement was made up as follows:

	Per cent
Tankage	50
Linseed Oil Meal	25
Fishmeal	15
Iodized Salt	5
Limestone	5

It has been found that on this ration, particularly when self-fed, pigs are often over-finished and suffer a cut in market value.

Consideration has been given to lowering the amount of barley, increasing the amount of oats and changing the amount of protein-mineral supplement in this ration.

---

[1] Contribution No. 180. Division of Chemistry, Science Service, in co-operation with Division of Animal Husbandry, Experimental Farms Service, Canada Department of Agriculture, Ottawa.
[2] Chemist, Division of Chemistry, Science Service.
[3] Technicians, Division of Chemistry, Science Service.
[4] Principal Animal Husbandman, Division of Animal Husbandry, Experimental Farms Service.

TABLE 1.—RATIONS EMPLOYED IN DIGESTIBILITY TRIALS WITH SWINE

Ration No.	Constitution of Ration		Numbers given in Tabulation
	Barley %	Tankage %	
1	10	90	T9
2	80	20	T2
3	40	60	T6
4	20	80	T8
5	100	0	B
6	60	40	T4

TABLE 2.—SUMMARY OF COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL NUTRIENTS IN THE TOTAL RATIONS. (COEFFICIENTS IN PER CENT, RATION NUMBERS IN BRACKETS GIVEN ONLY IN FIRST SQUARE, MISSING VALUES IN SQUARE BRACKETS)

Nutrient	Period No.	Coefficients of digestibility in per cent for following animals*						Means
		11	12	13	14	15	16	
Dry matter	1	[59(T9)]	78(T2)	85(B)	72(T4)	63(T8)	66(T6)	72.8
	2	69(T4)	61(T6)	74(T2)	56(T8)	56(T9)	81(B)	66.2
	3	74(T2)	82(B)	62(T8)	[55(T9)]	61(T6)	67(T4)	69.2
	4	60(T6)	52(T9)	67(T4)	75(T2)	80(B)	56(T8)	65.0
	5	80(B)	53(T8)	52(T9)	61(T6)	67(T4)	73(T2)	64.3
	6	[58(T8)]	69(T4)	62(T6)	80(B)	73(T2)	55(T9)	67.8
	Means	70.8	65.8	67.0	68.8	66.7	66.3	67.3
Organic matter	1	77	83	86	80	77	78	80.8
	2	78	75	80	74	75	82	77.3
	3	82	83	76	75	74	77	78.4
	4	73	71	77	80	81	74	76.0
	5	81	70	71	76	77	79	75.7
	6	75	79	75	82	80	75	78.2
	Means	78.5	76.8	77.5	78.4	77.3	77.5	
Nitrogen	1	86	86	88	85	86	82	85.4
	2	81	85	83	84	86	82	83.5
	3	81	84	85	85	82	80	82.4
	4	82	84	82	83	80	82	82.2
	5	80	81	83	82	80	82	81.3
	6	82	84	82	82	81	83	82.4
	Means	81.0	84.0	83.8	83.2	82.5	81.8	
Ether extract	1	97	91	61	95	96	96	87.8
	2	96	96	90	96	97	68	90.5
	3	95	70	97	101	96	94	90.4
	4	96	96	94	93	44	96	86.4
	5	52	96	96	96	94	91	87.5
	6	94	96	91	56	91	96	86.0
	Means	84.8	90.8	88.2	87.2	86.3	90.2	
T.D.N. in dry matter	1	65	79	84	74	65	69	74.2
	2	72	68	76	64	64	81	70.8
	3	79	82	65	64	67	71	72.8
	4	66	61	72	77	80	64	70.0
	5	80	61	60	68	71	75	69.2
	6	63	72	66	80	76	63	71.4
	Means	74.3	70.5	70.5	72.6	70.5	70.5	
Energy	1	77	80	85	77	76	77	79.0
	2	76	72	76	70	75	81	75.0
	3	80	82	76	75	73	75	77.2
	4	70	70	74	79	80	73	74.3
	5	79	66	69	70	74	76	72.3
	6	72	75	71	80	77	75	75.6
	Means	76.3	74.2	75.2	75.2	75.8	76.2	

* Individual values calculated to one decimal place but tabulated in round numbers to conform with editorial policy.

The Division of Chemistry is carrying out a series of digestion trials with swine to determine if variations in the proportions of basal grains and in the proportion of protein supplements to the grain mixture will affect their digestibility. In view of the contemplated changes in the Advanced Registry Feeding Station ration, it was considered advisable to use the Advanced Registry Ration for further studies of the associative digestibility between swine feeds.

Three experiments were planned and completed as follows:

(1) Associative digestibility between barley and tankage.

(2) Associative digestibility between the three basal grains, barley, wheat and oats, with the protein-mineral supplements maintained constant.

(3) Associative digestibility between the protein-mineral supplement and the grains with the ratio of the three grains to each other kept constant.

The results of the first of these are given in the present paper. The results of the other two will appear in subsequent papers.

PROCEDURE

Digestibility trials were carried out on rations of No. 1 Western Feed Barley and tankage. These are listed in Table 1. The chemical compositions are given in Table 8 of the appendix.

Six purebred Yorkshire barrows were used. Their weights throughout the experiment are given in Table 9 in the appendix. The six rations were fed to the six animals during six periods in the form of a 6 x 6 randomized Latin square. Each period consisted of 21 days—4 days change-over, 7 days preliminary and 10 days collection. As far as possible the animals were fed according to feeding standards. The feed was given in the form of a slop. Supplements of feeding oil, iodized salt, nicotinic acid and pantothenate were given. No calcium or phosphorous was given. The barley was cracked.

PROGRESS OF EXPERIMENT

There were feed refusals in period 1 on the 90 per cent tankage ration, in period 3 on the 90 per cent tankage ration and in period 6 on the 80 per cent tankage ration. The results from these three digestion trials were not used. In period 4, the 90 per cent tankage ration was being refused in the second half of the 10-day collection period. Therefore, the results for only the first five days were used. In period 5, the animal on barley did not eat too well during the change-over period, therefore the preliminary period was lengthened. This reduced the collection period to six days. Apart from these cases the trials proceeded satisfactorily. There were, then, three missing values in the Latin square.

RESULTS

A summary of the coefficients of digestibility is given in Tables 2 and 3. The data have been arranged in 6 x 6 Latin squares. The missing values have been included in brackets.

The analysis of variance is given in Table 4.

TABLE 3.—MEAN COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL NUTRIENTS IN THE TOTAL RATIONS ARRANGED BY RATIONS

Nutrient	Coefficients of digestibility, in per cent, of following rations					
	T9	T8	T6	T4	T2	B
Dry matter	53.7	58.0	61.8	68.5	74.5	81.3
Organic matter	73.0	74.2	75.2	78.0	80.7	82.5
Nitrogen	84.0	83.6	82.5	82.0	82.7	82.7
Ether extract	96.3	96.2	95.2	94.8	91.8	58.5
T.D.N. in dry matter	62.0	63.8	67.3	72.0	77.0	81.2
Energy	72.3	72.2	72.2	75.2	78.0	81.2

TABLE 4.—ANALYSIS OF VARIANCE OF DATA IN TABLES 2 AND 3

Nutrient	Variance due to	Designation	D/F	Sums of Squares	Variance	F*
Dry matter	Total	Original	32	3,013		
	Error	Complete	17	43	2.53	
	Per. + An. + Rat.	Diff.	15	2,970		
	Per. + An.	#	10	398	39.80	†
	Ration	Diff.	5	2,572	514.40	†
Organic matter	Total	Original	32	505		
	Error	Complete	17	60	3.53	
	Per. + An. + Rat.	Diff.	15	445		
	Per. + An.	#	10	116	11.60	3.29
	Ration	Diff.	5	329	65.80	†
Nitrogen	Total	Original	32	129		
	Error	Complete	17	31	1.82	
	Per. + An. + Rat.	Diff.	15	98		
	Per. + An.	#	10	83	8.30	4.56
	Ration	Diff.	5	15	3.00	1.65
Ether extract	Total	Original	32	7,038		
	Error	Complete	17	333	19.59	
	Per. + An. + Rat.	Diff.	15	6,705		
	Per. + An.	#	10	258	25.80	1.32
	Ration	Diff.	5	6,447	1,289.40	†
T.D.N. in dry matter	Total	Original	32	1,565		
	Error	Complete	17	22	1.29	
	Per. + An. + Rat.	Diff.	15	1,543		
	Per. + An.	#	10	176	17.60	†
	Ration	Diff.	5	1,367	273.40	†
Energy	Total	Original	32	580		
	Error	Complete	17	51	3.00	
	Per. + An. + Rat.	Diff.	15	529		
	Per. An.	#	10	178	17.80	5.93
	Ration	Diff.	5	351	70.20	†

* Nec. F. for $N_1 = 10$, $N_2 = 17$ at P of 0.05 = 2.46.
Nec. F. for $N_1 = 5$, $N_2 = 17$ at P of 0.05 = 2.81.

Obtained from analysis of variance of data when arranged by animals and periods, ignoring rations and using Yates' (5) method for incomplete blocks as outlined by Goulden (3).

† Obviously significant.

The statistical methods for these operations were as follows. The missing values were estimated by Yates' method as outlined by Cochran and Cox (1). The total sums of squares were calculated from the original values and the error sums of squares from the complete values. The difference gave the sums of squares due to period, animal and ration. To determine the variance contributed by the periods and animals, a suggestion by Yates (6), adapted by Goulden (personal communication) was used. The data were arranged by animals and periods, ignoring ration effects. Missing values and subsequent analyses of variance were calculated by Yates' (6) method as outlined by Goulden (3) for incomplete randomized blocks. From this the sums of squares for periods and animals were determined. It will be seen from Table 4 that a significant variance was contributed by animals plus periods. The standard errors for single

TABLE 5.—STANDARD ERRORS OF COEFFICIENTS OF DIGESTIBILITY OF SINGLE MEANS FOR INDIVIDUAL NUTRIENTS OF RATIONS IN TABLE 3

No. of missing values in ration mean	Standard errors of coefficients of digestibility of following nutrients					
	Dry matter	Organic matter	Nitrogen	Ether extract	T.D.N. in dry matter	Energy
None	0.65	0.77	0.55	1.81	0.46	0.71
One	0.80	0.94	0.68	2.21	0.57	0.87

TABLE 6.—COMPARISON OF MEANS OF OBSERVED COEFFICIENTS OF DIGESTIBILITY WITH THE THEORETICAL VALUES OF RATIONS CONTAINING 20, 40, 60 AND 80 PER CENT OF TANKAGE, RESPECTIVELY

Ration		Designation	Mean coefficients of digestibility in per cent of following nutrients					T.D N. in per cent of dry matter
Barley %	Tankage %		Dry matter	Organic matter	Nitrogen	Ether extract	Gross energy	
20	80	Observed	58.0	74.3	83.3	95.8	72.2	63.7
		Theoretical	57.8	75.3	84.4	96.4	74.4	64.6
		Difference	+0.2	−1.0	−1.1	−0.6	−2.2	−0.9
		"t" *	0.25	1.06	1.62	0.27	2.53	1.58
40	60	Observed	61.8	75.2	82.5	95.2	72.2	67.3
		Theoretical	63.5	77.5	84.2	94.2	76.2	68.6
		Difference	−1.7	−2.3	−1.7	+1.0	−4.0	−1.3
		"t" *	2.61	2.98	3.09	0.56	5.63	2.83
60	40	Observed	68.5	78.0	82.0	94.8	75.2	72.0
		Theoretical	69.3	79.4	83.9	90.5	77.9	72.7
		Difference	−0.8	−1.4	−1.9	+4.3	−2.7	−0.7
		"t" *	1.23	1.82	3.45	2.38	3.80	1.52
80	20	Observed	74.5	80.7	82.7	91.8	78.0	77.0
		Theoretical	75.2	81.0	83.5	83.0	79.6	76.9
		Difference	−0.7	−0.3	−0.8	+8.8	−1.6	+0.1
		"t" *	1.08	0.39	1.45	4.86	2.25	0.22

* Necessary "t" for N = 17, P of 0.05 = 2.11.
Necessary "t" for N = 17, P of 0.01 = 2.90.

Table 7.—Mean coefficients of digestibility and total digestible nutrients in dry matter of tankage calculated from the mixed rations with barley. (Means of six values)

Ration		Coefficients of digestibility in per cent of following nutrients in tankage					T.D.N. in per cent of dry matter
Barley	Tankage	Dry matter	Organic matter	Nitrogen	Ether extract	Energy	
%	%						
10	90*	52	72	84	97	72	61
20	80*	53	71	84	97	70	60
40	60	50	68	83	99	66	58
60	40	50	68	82	103	63	58
80	20	49	69	82	112	64	60

* Including missing values.

means and for the differences between two means were determined by a method outlined by Cochran and Cox (1). Period 1 gave results which were higher than those of the other periods.

To determine whether or not there were any associative effects the following procedure was adopted. From the 90 per cent tankage ration the coefficients of digestibility of tankage were calculated. Estimates of missing values were included. Using the means of these and the means of the coefficients of barley as base values, theoretical coefficients of digestibility of the remaining rations were estimated. These were compared with the means of the observed values. If the tankage in the 90 per cent ration had different coefficients than in the other rations or if the tankage in the other rations affected their digestibility, then, this would be evident from the differences between the observed and theoretical values for any one ration. Theoretical values were taken as zero values. The differences between these and the observed ones were treated according to Fisher's method for unique samples (2). The standard errors of the single means of the coefficients of digestibilities of the individual nutrients were calculated from the analysis of variance in Table 4, as explained previously. These are given in Table 5.

The comparison of the mean observed values with the theoretical ones is given in Table 6. The results for dry matter, organic matter and T.D.N. in the dry matter will first be considered. For rations containing 80, 60 and 20 per cent tankage, the differences between the observed and theoretical values were small, more than half of them being less than 0.5 per cent. They were not statistically significant. That means that there were no associative effects as far as these nutrients were concerned in rations containing, respectively, 90, 80, 40 and 20 per cent tankage. In the ration containing 60 per cent tankage, the observed values for dry matter and organic matter were 2 per cent lower and for the T.D.N. one per cent lower than the theoretical. These differences were statistically significant.

With the ether extract the differences progressively increased as the tankage in the ration decreased. At 40 per cent and 20 per cent levels of tankage they were large and significant. This may be due, at least in

part, to an artefact. The ether extract, in barley, is low—about 1.8 per cent. Any ether extract in the feces of body origin would greatly affect the apparent coefficient of digestibility of the ether extract of barley. The fatty acids in barley fat are composed of approximately 44 per cent linoleic acid, 27 per cent oleic, 7 per cent palmitic, 3 per cent stearic and 0.4 per cent linolenic. This mixture should be highly digestible. The apparent coefficient of digestibility in this experiment was 58 per cent. The per cent ether extract in tankage was over ten. If the "true" value for the barley were higher than the apparent, then it would become more and more apparent in the theoretical values as the barley increased and the tankage decreased.

With regard to the energy the observed values were from two to four per cent lower than the theoretical ones. These results were not in agreement with those for the T.D.N. Feces from animals receiving high tankage rations were very high in ash. From 40 to 60 per cent was found. The caloric value per gram of organic matter was highest in the high ash feces and lowest in the feces from animals which received either barley alone or small amounts of tankage. The chemical composition revealed no reason for this difference. It was concluded that the high ash in some way interfered with the caloric determinations. The possibility was considered that calcium soaps might be formed. These would remain undigested and pass into the feces. The soaps are insoluble in fat solvents and would not appear in the ether extract fraction. To test this idea, feces from rations containing varying quantities of tankage were extracted by the method of Wood and Simpson (5). The principle of the method is acid hydrolysis, followed by extraction.

With rations containing 90, 60, 40 and 20 per cent of tankage respecttively, the fat by the acid hydrolysis method was, respectively, in round figures, 12 per cent, 6 per cent, 5 per cent and 3 per cent. By the usual petroleum ether extraction method, the fat was respectively, in round figures, 0.5, 0.6, 0.7 and 1.4 per cent. When conventional caloric values were applied to the protein, carbohydrates and fat obtained by the hydrolysis method, the caloric value was similar to that obtained in the bomb calorimeter. The influence of rations containing a high content of calcium on the digestibility of fats is being studied in an independent investigation.

With nitrogen there were no statistical differences for rations containing 80 and 20 per cent tankage. In the rations containing 60 and 40 per cent tankage the observed values were between one and two per cent lower than the theoretical. These differences were significant. The mean coefficients of digestibility of tankage calculated from the mixed rations are shown in Table 7. It will be observed that for the dry matter, organic matter, nitrogen and T.D.N. in the dry matter there was little difference between the values for tankage in the various rations. The values for the energy were lower and for the ether extract higher in the rations containing smaller quantities of tankage. These points were dealt with above.

This discussion has shown a comparison between the coefficients of digestibility and the T.D.N. in the dry matter of barley and tankage in the 90 per cent tankage ration and the same values in the 80, 60, 40 and 20 per cent tankage rations. Certain variations have been noted. It is

concluded that, as a general rule, when barley and tankage are mixed together in widely varying proportions in swine rations there are no associative digestibility effects.

SUMMARY AND CONCLUSIONS

1. Six pure bred Yorkshire barrows were fed five rations of barley and tankage and one of barley alone.

2. The tankage was added to the rations in proportions of 90, 80, 60, 40 and 20 per cent of the mixture.

3. Digestibility trials were carried out.

4. Statistical procedures were described by means of which the digestibilities of the rations could be compared with theoretical ones representing the absence of associative digestibility effects.

5. The high ash content of the tankage appeared to interfere with the digestibility of the fat of that feed.

6. This point will be studied in a separate investigation.

7. It was concluded, on the basis of these comparisons, that as a general rule, there were no associative digestibility effects between barley and tankage.

ACKNOWLEDGMENTS

Acknowledgment is made to C. H. Goulden, Dominion Cerealist, for the advice on the statistical treatment; to Messrs. Angus, Baker, Lalonde and Sample, for technical assistance in carrying out the digestibility trials; to R. Carson and staff for chemical analyses of the samples.

REFERENCES

1. Cochran, W. G., and Gertrude M. Cox. Experimental designs, p. 98. John Wiley & Sons, Inc., New York. 1950.
2. Fisher, R. A. Statistical methods for research workers, p. 117. Oliver and Boyd, London. 1934.
3. Goulden, C. H. Methods of statistical analysis. John Wiley & Sons, Inc., New York. 1939.
4. Jones, D. B. Factors for converting percentages of nitrogen in feeds into percentages of protein. U. S. Department of Agr. Circular No. 183. 1931.
5. Wood, E. C., and T. W. Simpson. An improved method for the routine determination of fat in feces. Analyst 59:817-818. 1934.
6. Yates, F. The analysis of replicated experiments when the field results are incomplete. Emp. Jour. Exp. Agr. 1:129-142. 1933.

APPENDIX

Table 8.—Chemical composition of feedstuffs. (Means of six values)

Feedstuff	Original dry matter	Composition of Dry Matter					
		Ash	Protein*	Ether extract	Crude fibre	Nitrogen-free extract	Energy Therms per kilogram
	%	%	%	%	%	%	
Barley	87.28	2.99	14.36	1.77	6.48	74.40	4.55
Tankage	92.17	35.03	47.24	11.08	2.31	4.34	3.85

* Protein factors: Barley—N x 5.83 (4) Tankage—N x 6.25.

TABLE 9.—LIVE WEIGHTS OF ANIMALS

Animal No.	Weight in kilograms in following periods*						Gains	
	1	2	3	4	5	6	Total	Daily‡
11	—	40	51	63	67	—	—	—
12	49	55	72	75	79	83	34	0.26
13	49	60	68	79	79	96	47	0.36
14	37	40	—	63	66	93	56	0.42
15	36	42	52	70	86	130	67	0.51
16	48	60	71	83	96	101	53	0.40
Means	44	50	63	72	79	95	51	0.39

* The weights for each period are the average of single weights before and after the collection sub-period.
‡ Length of trial from the middle date of the first period to the middle date of the sixth period = 132 days.

DIGESTIBILITY STUDIES WITH SWINE

V. ASSOCIATIVE DIGESTIBILITY BETWEEN THE GRAINS IN THE CANADIAN ADVANCED REGISTRY SWINE TESTING RATION[1]

C. J. Watson[2], W. M. Davidson[3], J. W. Kennedy[3], and E. B. Fraser[4]

[Received for publication July 27, 1950]

In a previous publication (3) reference was made to the Canadian Advanced Registry Swine Testing Ration. It consists of the three basal grains, barley, wheat and oats, with a protein-mineral supplement containing tankage, fishmeal, linseed oil meal, iodized salt and limestone. It was stated that a series of digestibility trials had been carried out to determine if any associative digestibility effects existed between the various components in the ration. The results of the first series of digestion trials were reported in that paper. Barley and tankage were fed together in varying proportions. It was concluded that there were no associative effects between these two feeds as far as total digestible nutrients were concerned. It was suggested that the high calcium in tankage rendered fats insoluble by forming calcium soaps.

In the present paper the grains, barley, wheat and oats, were fed in different proportions to one another with the protein-mineral supplement maintained at a constant level. The effect of the association of the grains with one another in different proportions on their digestibility was determined. The rations fed are given in Table 1. The numbers were assigned at random. These rations can be divided into four groups;

(1) The four components, barley, wheat, oats and the protein-mineral supplement fed alone as the sole ration.

(2) Barley and oats in varying proportions to one another with a constant quantity of protein supplement.

(3) Barley, wheat and oats in varying proportions to one another with a constant protein supplement.

---

[1] Contribution No. 184, Division of Chemistry, Science Service, Canada Department of Agriculture. Ottawa, in co-operation with the Division of Animal Husbandry, Experimental Farms Service.
[2] Chemist, Division of Chemistry, Science Service.
[3] Technicians, Division of Chemistry, Science Service.
[4] Principal Animal Husbandman, Experimental Farms Service.

Table 1.—Constitution of rations

Ration No.	Proportions of grains in grain portion			Protein-mineral supplement added
	Barley %	Wheat %	Oats %	%
1	100	0	0	0
2	80	20	0	15
3	60	20	20	15
4	0	0	100	0
5	0	0	0	100
6	40	0	60	15
7	40	20	40	15
8	20	20	60	15
9	60	0	40	15
10	80	0	20	15
11	100	0	0	15
12	0	100	0	0

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS OF TOTAL RATIONS

Ration* No.	Designation	Coefficients of digestibilities in per cent of following nutrients†						T.D.N. in dry matter %
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N.F.E.	
1	Individual values	82	83	85	38	22	89	82
		81	82	83	62	16	88	81
		80	82	83	38	21	88	80
		81	82	81	52	21	91	81
	Means	80.8	82.3	83.1	47.4	20.2	88.8	80.9
2	Individual values	82	84	83	87	27	89	83
		80	83	83	88	17	87	81
		78	81	82	83	12	86	79
		79	82	81	84	20	87	80
	Means	79.8	82.5	82.5	85.3	19.2	87.4	80.8
3	Individual values	78	81	83	87	20	86	80
		78	80	84	88	14	85	79
		76	79	82	83	16	84	78
		77	80	82	84	22	85	79
	Means	77.6	80.0	83.0	85.7	18.2	84.9	78.7
4	Individual values	64	66	84	82	10	73	67
		65	67	85	88	−1	74	68
		65	67	82	73	24	78	67
		63	65	84	83	8	71	66
	Means	64.3	66.1	83.6	81.4	10.2	74.0	67.2
5	Individual values	62	73	79	95	34	55	68
		63	75	79	98	35	18	70
		63	74	79	96	31	26	69
		61	72	79	92	22	52	67
	Means	62.2	73.8	79.1	95.4	30.5	37.8	68.3
6	Individual values	70	72	81	89	10	78	72
		72	74	83	91	8	80	74
		73	75	84	85	28	88	74
		68	70	80	87	6	76	70
	Means	70.6	72.9	82.0	87.9	13.1	80.6	72.5
7	Individual values	73	75	82	85	9	81	74
		76	79	85	88	14	84	78
		75	77	83	83	18	82	76
		74	76	83	84	10	82	75
	Means	74.4	76.6	83.0	85.0	12.8	82.0	75.7
8	Individual values	74	76	85	81	24	82	76
		74	76	84	85	13	82	76
		72	75	82	86	27	80	74
		70	72	81	88	11	78	72
	Means	72.7	75.1	82.7	85.0	18.6	80.2	74.6

(continued on page 478)

* Rations corresponding to numbers listed in Table 1.
† Calculated to one place of decimals, shown here in units to comply with editorial policy.

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY OF NUTRIENTS OF TOTAL RATIONS—*Concluded*

Ration* No.	Designation	Coefficients of digestibilities in per cent of following nutrients†						T.D.N. in dry matter %
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N.F.E.	
9	Individual values	73	76	82	87	5	81	75
		76	78	85	88	14	84	77
		72	74	76	79	15	80	73
		74	76	91	89	18	81	76
	Means	73.7	76.1	83.5	85.9	12.9	81.8	75.2
10	Individual values	78	81	85	90	21	85	79
		77	80	82	89	15	85	78
		76	79	81	76	21	82	77
		75	78	79	83	17	84	76
	Means	76.8	79.3	81.8	84.5	18.5	83.9	77.8
11	Individual values	80	83	84	87	22	87	81
		79	82	82	85	18	87	80
		75	78	78	80	11	84	75
		78	81	82	85	16	87	80
	Means	78.3	81.0	81.7	84.1	16.8	86.3	78.8
12	Individual values	89	90	91	79	18	93	90
		89	90	91	76	26	92	89
		88	89	91	69	21	92	88
		87	88	90	72	10	92	88
	Means	88.3	89.1	90.8	73.9	18.7	92.2	88.7

* Rations corresponding to numbers listed in Table 1.
† Calculated to one place of decimals, shown here in units to comply with editorial policy.

(4) Barley with the protein-mineral supplement and barley with wheat and the protein-mineral supplement.

The description of the feeds is as follows:

(1) *Barley*—"Velvet" variety, grown at the Experimental Farm, Ottawa, medium ground before each digestion trial.
(2) *Wheat*—No. 1 Western Canada Feed, medium ground before each trial.
(3) *Oats*—No. 1 Western Canada Feed, medium ground before each trial.
(4) *Tankage*—Canada Packers Company, Montreal, P.Q.
(5) *Linseed oil meal*—Sherwin-Williams Company Limited, Montreal. Screw-press process.
(6) *Fishmeal*—White fish meal, "Faster Fat" Company, Halifax, NS..

The chemical compositions of the feeds are given in Table 5 in the appendix. The animals received vitamin A and D feeding oil throughout the experiment. The amount of daily ration in each period was based on the live weights of the pigs. The ration was fed as a slop. The experimental animals were eight purebred Yorkshire barrows, numbered in the experiment 1 to 8. The live weights are given in Table 6 of the appendix.

TABLE 3.—STANDARD ERRORS OF MEAN COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL NUTRIENTS. (MEAN OF FOUR VALUES)

Nutrient	Standard error
Dry matter	0.85
Organic matter	0.85
Nitrogen	1.38
Ether extract	1.79
Crude fibre	3.04
N-free extract	1.15
T.D.N. in dry matter	0.90

There were six digestion periods. Each period consisted of a pre-experimental sub-period of four days, a change-over sub-period of 3 days, a preliminary sub-period of 7 days and a collection sub-period of 10 days. The 12 rations were distributed to the 8 pigs through the 6 periods in a cyclic order. There were thus four replicated results for each ration. The experiment was commenced in May 1946 and concluded in September 1946.

PROGRESS OF THE EXPERIMENT

Animals 2 and 3 in period 1 and animal 4 in period 2 shed some hair in the feces. Animals 2 and 3 in period 3 and animal 6 in period 5 had some worms. Animal 2 in period 6 refused some feed during the second half of the collection sub-period. The results of the first five days were used in the calculations. Otherwise the experiment was completed satisfactorily.

RESULTS

A summary of the coefficients of digestibility is given in Table 2. In this table rations 1, 4, 5 and 12 consisted of the single components of the Advanced Registry ration. Rations 2, 3, 6, 7, 8, 9, 10 and 11 were mixtures of two or more of these components as shown in Table 1. To detect possible associative effects the following procedure was adopted. The results for rations 2, 3, 6, 7, 8, 9, 10 and 11 were arranged in columns of four replicates each and analysed statistically. The variance was separated into that due to rations and that due to replicates. This latter was taken as the error of the experiment. From it an estimate was made of the standard error of a single mean of four values. These standard errors for the different nutrients are given in Table 3. Using the values of the four components when each was fed alone, theoretical mean values of the mixed rations were calculated. These were compared with the observed means determined in the digestion trials. Using Fisher's method (1) for unique samples the differences between the observed and theoretical values were divided by the standard errors listed in Table 3. The results are given in Table 4.

It will be observed that for the dry matter, organic matter, nitrogen, nitrogen free extract and T.D.N. in dry matter, the differences were small and not statistically significant. With the ether extract there were larger differences, the observed values being higher than the theoretical. This

TABLE 4.—COMPARISON OF MEAN OBSERVED COEFFICIENTS OF DIGESTIBILITY OF TOTAL RATIONS WITH CALCULATED THEORETICAL VALUES. (MEANS OF FOUR OBSERVED VALUES, EACH RATION INCLUDES 15% OF PROTEIN-MINERAL SUPPLEMENT)

Designation	Mean coefficients of digestibility in per cent with difference and "t" values for following rations							
Ration No.	11	2	6	9	10	8	7	3
Barley %	100	80	40	60	80	20	40	60
Wheat %	0	20	0	0	0	20	20	20
Oats %	0	0	60	40	20	60	40	20
Dry matter								
Observed	78.3	79.8	70.6	73.7	76.8	72.7	74.4	77.6
Theoretical	78.2	79.4	69.6	72.5	75.3	70.9	73.8	76.6
Difference	+0.1	+0.4	+1.0	+1.2	+1.5	+1.8	+0.6	+1.0
"t"*	0.12	0.47	1.18	1.41	1.76	2.12	0.71	1.18
Organic matter								
Observed	81.0	82.5	72.9	76.1	79.3	75.1	76.6	80.0
Theoretical	81.3	82.5	72.7	75.6	78.4	73.9	76.8	79.6
Difference	−0.3	0.0	+0.2	+0.5	+0.9	+1.2	−0.2	+0.4
"t"*	0.35	—	0.24	0.59	1.06	1.41	0.24	0.47
Nitrogen								
Observed	81.7	82.5	82.0	83.5	81.8	82.7	83.0	83.0
Theoretical	81.6	82.7	81.7	81.7	81.7	82.8	82.8	82.7
Difference	+0.1	−0.2	+0.3	+1.8	+0.1	−0.1	+0.2	+0.3
"t"*	0.07	0.14	0.22	1.30	0.07	0.07	0.14	0.22
Ether extract								
Observed	84.1	85.3	87.9	85.9	84.5	85.0	85.0	85.7
Theoretical	74.5	72.2	80.6	77.5	73.7	82.8	79.8	76.4
Difference	+9.6	+13.1	+7.3	+8.4	+10.8	+2.2	+5.2	+9.3
"t"*	5.36	7.32	4.08	4.69	6.03	1.23	2.91	5.20
Crude fibre								
Observed	16.8	19.2	13.1	12.9	18.5	18.6	12.8	18.2
Theoretical	21.2	21.1	13.6	15.5	17.9	13.2	15.0	17.5
Difference	−4.4	−1.9	−0.5	−2.6	+0.6	+5.4	−2.2	+0.7
"t"*	1.45	0.63	0.16	0.86	0.20	1.78	0.72	0.23
N-free extract								
Observed	86.3	87.4	80.6	81.8	83.9	80.2	82.0	84.9
Theoretical	87.1	87.8	78.8	81.7	84.4	79.6	82.5	85.2
Difference	−0.8	−0.4	+1.8	+0.1	−0.5	+0.6	−0.5	−0.3
"t"*	0.70	0.35	1.57	0.09	0.43	0.52	0.43	0.26
T.D.N. in dry matter								
Observed	78.8	80.8	72.5	75.2	77.8	74.6	75.7	78.7
Theoretical	78.8	80.4	72.0	74.3	76.7	73.4	75.6	78.1
Difference	0.0	+0.4	+0.5	+0.9	+1.1	+1.2	+0.1	+0.6
"t"*	—	0.44	0.56	1.00	1.22	1.33	0.11	0.67

* "t" is determined by dividing the differences by the standard error in Table 3.
Nec. t at N of 24 for P of 0.05 = 2.03.
Nec. t at N of 24 for P of 0.01 = 2.72.

may possibly be due to an artefact. The amount of ether extract in the barley and wheat is quite low, being of the order of $1\frac{1}{2}$ per cent of the dry matter. When these were fed as sole rations, a small amount of fecal fat of body origin would appreciably lower the apparent coefficients of digestibility. When mixed with the protein mineral supplement which contains considerable ether extract or with oats, also containing a fair amount of extract, the presence of the fecal metabolic fat would have less influence on the total apparent digestibility. This suggestion is borne out by the results of rations 6, 9 and 10 and also for 8, 7 and 3. As the relative quantities of barley or barley plus wheat were reduced, the differences between the observed and theoretical values became less.

With the crude fibre the differences were generally small. There were two rather wide variations. The experimental error was higher than for the other nutrients. The differences were not statistically significant. The digestibility was low.

On the basis of the contents of the T.D.N. in the dry matter and the digestibilities of the nitrogen, dry matter and organic matter, it was concluded that there were no associative effects between the three grains in the Advanced Registry Ration when they were fed with a constant quantity of the protein-mineral supplement.

SUMMARY AND CONCLUSION

1. A study was made of the associative digestibility between the three basal grains of the Canadian Advanced Registry Swine Testing Ration.

2. These grains were barley, wheat and oats.

3. Using eight pure bred Yorkshire barrows digestion trials were carried out on rations containing these three feeds in varying amounts.

4. A constant percentage of protein-mineral supplement was included in the rations.

5. It was concluded that there were no associative digestibility effects between the three grains.

ACKNOWLEDGMENTS

Acknowledgment is made to Messrs. Angus, Lalonde, Baker and Sample for assistance in carrying out the digestion trials, and to R. B. Carson and his staff for carrying out the chemical analyses of the samples.

REFERENCES

1. Fisher, R. A. Statistical methods for research workers, p. 117. Oliver and Boyd, London. 1934.
2. Jones, D. B. Factors for converting percentages of nitrogen in feeds into percentages of protein. U.S. Dept. of Agr. Circular No. 183. 1931.
3. Watson, C. J., J. W. Kennedy, W. M. Davidson and E. B. Fraser. Digestibility studies with swine. IV. Associative digestibility between barley and tankage. Sci. Agr. 30: 467-475.

APPENDIX

Table 5.—Chemical composition of feedstuffs (means of six values)

Feedstuff	Original dry matter	Composition of dry matter				
		Ash	Protein*	Ether extract	Crude fibre	N-Free extract
Barley	87.12	3.00	13.86	1.63	6.34	75.17
Wheat	87.19	2.01	14.78	1.51	3.55	78.15
Oats	87.85	3.56	12.46	3.42	13.12	67.42
Tankage	90.61	27.78	55.55	8.71	2.43	5.53
Linseed oil meal	91.03	6.13	31.18	8.98	9.19	44.51
Fish meal	89.98	21.46	75.01	5.03	– –	– –

* Protein factors: Grains—N × 5.83 (Jones (2)) Linseed oil meal—N × 5.30 (Jones (2))
Tankage and fish meal—N × 6.25.

Table 6.—Live weights of animals in kilograms*

Animal No.	Weights by following periods						Gains	
	1	2	3	4	5	6	Total	Daily #
1	68	87	106	117	132	143	75	0.54
2	73	90	109	121	134	149	76	0.55
3	64	79	98	103	120	136	72	0.52
4	67	83	101	119	131	146	79	0.57
5	63	80	100	114	131	146	83	0.60
6	63	80	99	111	115	133	70	0.50
7	60	77	93	107	127	148	88	0.63
8	73	81	101	117	132	148	75	0.54
Means	66	82	101	114	128	144	78	0.56

* Weights for each period are average of single weighings before and after collection periods.
# From middle date of two weighings in period 1 to middle date of two weighings in period 6 = 139 days.

A BACTERIAL SOFT ROT OF GLADIOLUS[1]

L. W. Koch[2]

Laboratory of Plant Pathology, Harrow, Ontario.

[Received for publication July 28, 1950]

During the summer of 1949, attention was directed to a destructive soft rot of gladiolus plants in southwestern Ontario. As there appears to be no reference in the literature to a disease of this type, preliminary investigations were undertaken to determine its cause and to estimate its potentialities.

DISTRIBUTION OF THE DISEASE

The soft rot was first observed in a gladiolus plantation of four acres near Harrow, Ontario. The entire field had been irrigated a few times prior to the outbreak of the trouble, and at first it was thought that the occurrence of the disease might be connected with these applications of water. A survey of gladiolus plantings in the surrounding districts indicated, however, that the same disease was present in many unirrigated fields within a distance of 50 miles from Harrow, but to a lesser extent than in the first plantation. Late in the season, F. L. Drayton, of Ottawa, observed a disease with identical symptoms in a commercial gladiolus plantation at Oakville, Ontario, some 200 miles from Harrow, thus indicating that the disease was by no means localized in its occurrence.

REVIEW OF LITERATURE

In 1913, Severini (3), in Italy, described a soft rot of Gladiolus Colvillei and *Ixia maculata*, which, except for the symptoms on the corms, resembles the disease to be described in this paper. Severini isolated two apparently distinct bacteria. He found that one of these, which resembled *Bacillus aroideae* Towns., proved to be more virulent than the other, and demonstrated its pathogenicity on the species of *Gladiolus* and *Ixia* from which the organism was originally isolated and also on potato tubers. He named it *Bacillus ixiae*. Stevenson (4) reported the same disease in Holland.

According to Moore (1), a disease of gladiolus caused by *Bacillus omnivorus* van Hall (= *Bacterium carotovorum* (L. R. Jones) Lehm.), was described by Rainio (2) in Finland. It resembles in many respects the one found at Harrow and Oakville.

SYMPTOMS

The disease was most prevalent and severe on the gladiolus plants from which the upper portion of the flower-bearing stalks had been removed. On these plants, the symptoms consisted of chocolate brown, discoloured areas of variable extent, but usually beginning at the cut end of the flower stalk and extended downward towards the corm (Figure 1). Sometimes all of the leaves surrounding an infected flower stalk became involved, turned yellow, and died. In other plants, where the infection was confined to the remnant of the flower stalk or to the flower stalk and the immediately adjacent leaf sheath, various degrees of chlorosis and stunting were evident.

---

[1] Contribution No. 1039 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Officer-in-Charge.

Almost invariably, the pith of the brown flower stalk disappeared completely, with collapse and necrosis of the contiguous tissues. The basal portions of the inner leaves of affected plants were usually brown and necrotic.

The outer leaves were often water-soaked in appearance and deposits of a reddish gel-like exudate occurred between the broad leaf bases on the upper portion of the corms. Well defined oval to elongate lesions with a reddish brown halo were found on the leaves of the plant adjacent to the necrotic portions. In advanced stages, leaves were yellowed, streaked with brown, and finally became recumbent, dry, and chocolate brown.

An examination of the corms of affected plants throughout August showed that, in most of them, the disease had not extended into the corm itself, but in September, brown or black lesions, obviously the result of earlier stalk infection, were present on some of the corms. However, all of these lesions were superficial, and periodic examinations of these corms in common storage failed to detect any further progress of the disease. In late August, cormels were abundant on healthy plants, but there were few or none on the diseased ones (Figure 2).

Plants from small corms and some of those from which the flowers had not been cut, also exhibited the symptoms of the disease, as described above (Figure 2), in the absence of any visible injury to the flower stalks. In many such plants, however, corn borer larvae were present and apparently their tunnels served as infection courts for the pathogen.

THE CAUSAL ORGANISM AND ITS PATHOGENICITY

An examination of hand-sectioned gladiolus stalks and leaves from areas of incipient infection revealed an abundance of bacteria in the parenchymatous tissues. Isolations on potato dextrose agar from diseased tissues in all stages of the development of the disease invariably yielded bacterial colonies that were white and nearly spherical. The bacteria proved to be short rods, single or in chains, motile, and Gram-negative. The organisms isolated from the Harrow and the Oakville material were identical in every respect.

As the evidence provided by the symptoms, by the organism isolated, and by the microscopic appearance of the diseased tissue seemed to indicate that one of the soft-rotting organisms was involved, it was decided to carry out the pathogenicity trials on several of other plants and plant tissues in addition to the gladiolus.

Vigorously growing gladiolus plants in full bloom were selected for inoculation both in the greenhouse and in the field. Water suspensions of the bacteria from 24-hour old cultures on potato dextrose agar were swabbed on the exposed ends of freshly cut flower stalks with pieces of absorbent cotton and the exposed ends then bound with wax paper. Adequate control plants were prepared by swabbing the cut ends with sterilized water. The greenhouse plants were placed in a humidity chamber for 24 hours after inoculation and then returned to ordinary greenhouse conditions.

The other material used for inoculation included portions of potato tubers and carrot roots, and onion and tobacco plants. From the potatoes and carrots, cubes of internal tissues were removed aseptically and placed

FIGURE 1. Gladiolus plants affected with bacterial soft rot at various stages after removal of flower stalks.

FIGURE 2. Left—Bacterial soft rot of gladiolus plant from which flower stalk was removed. Note absence of cormels. Centre—Healthy gladiolus plant at same stage. Right—Infection of young plant prior to flower formation.

in sterile Petri dishes containing moist filter paper. Some of the cubes of each kind were then inoculated with bacteria from the potato dextrose agar slants and incubated at 30° C. The tobacco plants used in the experiment were of the burley type and were approaching maturity in the field. The stalks were broken off and the bacteria applied in water suspensions to the exposed ends of the rooted portions. Sterilized water was applied to the control plants. The broken ends of all plants were then bound with wax paper to prevent these surfaces from drying out. For the onion plant trials, the Valencia variety, a Sweet Spanish onion, was chosen on account of its high susceptibility to common bacterial soft rot. Plants were carefully removed from the field and potted in the greenhouse. The inoculations were made by cutting off several of the central leaves and then applying water suspensions of the bacteria or water alone to the cut ends, which were then bound with wax paper.

TABLE 1.—RESULTS OF INOCULATING VARIOUS PLANT TISSUES WITH BACTERIA ISOLATED FROM DISEASED GLADIOLUS PLANTS

Host material	Number		Conditions of experiment	Results
	Inoc.	Check		
Potato tuber (cubes)	4	4	Held at 30° C.	After 5-7 days*, all inoculated cubes showed partial to complete rotting. Checks healthy.
Potato tuber (cubes)	4	4	Held at 30° C.	(ditto)
Carrot (cubes)	4	4	Held at 30° C.	After 5 days, all inoculated cubes completely rotted. Checks healthy.
Carrot (cubes)	4	4	Held at 30° C.	(ditto)
Onion plants	6	6	Greenhouse temperature ± 30° C.	After 7 days, all inoculated plants showed partial rotting of central region of bulb. After 14 days, 3 bulbs completely rotted. Checks healthy.
Onion plants	5	5	Greenhouse temperature ± 26° C.	After 14 days, all inoculated bulbs partially or completely rotted.
Tobacco plants (stalks)	6	6	Field temperature	Negative. No signs of rotting.
Gladiolus plants	10	10	In field. Watered regularly.	After 5 days, inoculated flower stalks showed variable amount of necrosis in region of pith and watersoaking of external tissues. After 10 days, necrotic portion in most cases extended to corm. After 2 weeks, inoculated plants manifested typical field symptoms.
Gladiolus plants	5	5	Greenhouse temperature ± 30° C.	(ditto)

* All inoculated potato tuber, carrot and onion tissue manifested the disagreeable odour characteristic of tissues affected with bacterial soft rot, caused by *Erwinia carotovora*.

The results of these pathogenicity trials are summarized in Table 1. From these it is evident that all of the potato tuber and carrot cubes, the onion bulbs, and the gladiolus stalks rotted within a period of 5-14 days after inoculation with pure cultures of the bacteria isolated from the diseased gladiolus plants. On the other hand, the tobacco stalks remained unaffected, despite the fact that tobacco plants are known to be subject to bacterial soft rot.

The development of the disease on the inoculated gladiolus plants proved to be highly consistent. Ten days after inoculation, all of the plants showed discoloration of some or all of the leaves, extending down to the corms. This condition was accompanied by a softening and necrosis of the flower stalks and the adjacent tissues. After twenty days, all of the inoculated plants were stunted and developed smaller corms than did the uninoculated plants. The inoculated plants developed few or no cormels, and without exception, they showed varying degrees of chlorosis, accompanied by necrotic lesions near the base of the stalks. At that stage, the latter were in most cases brown and collapsed. Re-isolations from the diseased tissue of the inoculated plants yielded, without exception, bacteria which were similar in every respect to the ones isolated from the naturally infected plants.

It should be emphasized that the outstanding symptoms of this gladiolus disease are the chocolate brown to black discoloration of the flower stalks and the adjacent leaf sheath tissue and the disappearance of the pith.

CONCLUSIONS

It would appear that the organism responsible for this gladiolus disease closely resembles *Erwinia carotovora* (L. R. Jones), Holland. The symptomatology of the disease in naturally infected and artificially inoculated plants closely resembles that of the bacterial soft rot ascribed to *E. carotovora* in several vegetables and other plants. In addition, the pathological histology of the affected tissues, the range of susceptible plants, and the cultural characters and morphology of the causal organism, all provide evidence for this tentative identification.

It is possible that the environmental conditions prevailing in southern Ontario during 1949 were particularly favourable to the development of a disease of this kind. On the other hand, if these conditions provide the explanation for the sudden occurrence of the disease and the consequent damage to the gladiolus plants, it seems strange that an organism so common and widespread in the district has not caused the disease previously. The circumstances surrounding its possible recurrence in the immediate future may provide the explanation and indicate whether or not special measures for its control should be undertaken.

ACKNOWLEDGMENT

Acknowledgment is due W. G. Benedict of the Harrow laboratory for assistance rendered throughout the period of this investigation.

REFERENCES

1. Moore, W. C. Diseases of bulbs. Bull. 117, Min. of Agr. & Fish. 1939.
2. Rainio, A. J. Tutkimuksia Gladiolus—Kasvien bakteeritaudeista (*Pseudomonas marginata* McCl., Ps. *gummisudans* McCl., *Bacillus omnivorus* Hall. Ja B. variegatus Rainio nov. spec.) Ja niden torjunnasta Valt. Maaltalousk. Julk. 84, 102 pp. 1936.
3. Severini, G. Una bacteriosi dell' *Ixia maculata* e del *Gladiolus Colvillei*. Ann. Bot. Roma 2: 413-424. 1913.
4. Stevenson, J. A. Foreign plant diseases. U.S.D.A. 198 pp. 1926.

BOOK REVIEW

BOTANY by W. W. Robbins and T. E. Weier. John Wiley & Sons Inc., New York. 480 pages. 1950. $5.00.

Among the recently published texts in botany is this attractively illustrated book, written by two members of the staff of the University of California. The authors have attempted to arouse the interest of the student by giving an appreciation of the scope of botany and of its relation to agriculture, forestry, and medicine. The double-column format, together with nearly 500 well-labelled illustrations, combine to produce an interesting and easily read book.

The arrangement of the subject matter is much the same as is found in most general botany texts. The various parts of the plant (stem, root, etc.) are dealt with first, and then follows a discussion of the different groups of plants (algae, fungi, etc.). Among the topics covered in the 22 chapters are: The plant world; classification and naming of plants; plant cell; stem; roots; leaf; flower; fruit, seed, and seedlings; inheritance; plant as a living mechanism; groups of plants; fission plants; algae; fungi; viruses; bryophytes; vascular plants; and evolution.

Two of the errors in the book are of especial concern to Canadians. It is annoying, after reading on page 27 that "the coniferous forests of North America are shown in Fig. 2.10", to find that Fig. 2.10 features only the United States, with but a blank space to the north of the U.S.-Canada border. The second error is on page 227, where reference is made to *13* Canadian provinces. Fortunately the botanical information in the text is more reliable than the above-mentioned references and as an introduction to plant science this book is a valuable addition to the field.

W. H. MINSHALL,
Division of Botany & Plant Pathology,
Science Service, Ottawa.

SELECTED LIST OF ACCESSIONS

MAIN LIBRARY
DEPT. OF AGRICULTURE
SCIENCE SERVICE BUILDING

BIBLIOTHÈQUE CENTRALE
MINISTÈRE DE L'AGRICULTURE
ÉDIFICE DU SERVICE SCIENTIFIQUE

OTTAWA

Vol. 37, No. 11. November, 1950.

When borrowing publications, please give date of Selected List of Accessions, and the list number of each item desired.

1. An historical geography of Europe. 3d ed. rev. London, Methuen, 1948. 480 p il. maps. (Dutton advanced geographies.) Selected bibliography: pp. 449-471.
2. The history and social influence of the potato. Redcliffe N. Salaman. Cambridge, University press, 1949. 685 p. figs. plates. maps. bibliography: pp. 620-645.

AGRICULTURE—ECONOMIC ASPECTS

3. Problems of African development. Part I. Land and labour. T. R. Batten. London, Oxford university press, 1947. 178 p.

BACTERIOLOGY

4. Handbook of bacteriology for students and practitioners of medicine. Joseph W. Bigger. Sixth edition. London, Baillière, Tindall and Cox, 1949. 547 p. figs. col. plates.
5. Hans Zinsser, 1878-1940. Simeon B. Wolbach. (National academy of sciences. Biographical memoirs, vol. XXIV, 1947, pp. 323-347).

BEES

6. Queen rearing. Harry H. Laidlaw, jr. and J. E. Eckert. Hamilton, Illinois, Dadant & sons, inc., 1950. 147 p. figs.
7. Beekeeper's folly. John R. Ratcliff. London, Macdonald & co., ltd., 1949. 270 p. il. bibliography: pp. 259-261.

BIOLOGY

8. On the origin of species by means of natural selection. Charles Darwin. (Reprint of the first edition) Foreword by C. D. Darlington. London, Watts & co., 1950. 426 p.
9. A source-book of biological names and terms. Second edition. Edmund C. Jaeger. Springfield, Illinois, Charles C. Thomas, 1950. 287 p. figs.

BOTANY

10. Biology of plants. H. L. Dean. Dubuque, Iowa, Wm. C. Brown co., 1949. 265 p. il. figs. laboratory exercises.
11. Plants of New Zealand. R. M. Laing and E. W. Blackwell. Fifth edition, revised. Christchurch, Whitcombe and Tombs ltd., n.d. 499 p. figs. col. plates.
12. The ecology and distribution of Hepaticae in central and western New York. R. M. Schuster. Notre Dame, Indiana, University of Notre Dame press, 1950. 201 p. figs. (Reprinted from The American midland naturalist, vol. 42, no. 3, pp. 513-712, November, 1949).
13. The flora of Bic and the Gaspé peninsula, Quebec. H. J. Scoggan. Ottawa, King's printer, 1950. 399 p. il. tabs. (Canada. Department of resources and development. Development services branch. National museum of Canada. Bulletin no. 115. Biological series no. 39).
14. Studies in the post-glacial history of British vegetation. XI. Late-glacial deposits in Cornwall. Ann P. Conolly, H. Godwin, and Eleanor M. Megaw. (Royal society of London. Philosophical transactions. Series B. Biological sciences. No. 615. Vol. 234, pp. 397-469, 1950).

BOTANY—(Continued)

15. Etude botanique des copaliers du Congo belge. J. Léonard. Bruxelles, 1950. 158 p. il. (Institut national pour l'étude agronomique du Congo belge. Série scientifique no. 45).
16. Recherches sur la formation du pollen chez quelques angiospermes. Paule Terra. (Lyon. Université. Annales. Troisième série. Sciences. Section C. Sciences naturelles. VI. pp. 159-165).
17. Sao Paulo. Secretaria da agricultura. Instituto de botanica. Relatorio annual . . . por F. C. Hoehne. Sao Paulo, 1949. 102 p. il.
18. Bericht uber das Geobotanische forschungsinstitut Rübel in Zurich, 1949, von E. Rübel und W. Lüdi. Zurich, 1950. 117 p.
19. Trees and shrubs hardy in the British Isles. W. J. Bean. Vol. I. London, John Murray, 1950. 703 p. figs. plates. (7th edition).
20. A brief history of the development of botany and of the Department of botany at the University of Wisconsin to 1900. Geo. S. Bryan. (Wisconsin academy of sciences, arts and letters. Transactions, vol. XL, part 1, 1950. pp. 1-27).
21. Annual review of plant physiology. Volume 1, 1950. D. I. Arnon, editor. Stanford, California, Annual reviews, inc., 1950. 364 p.
22. A glossary of botanic terms with their derivation and accent. Benjamin Daydon Jackson. Fourth edition, revised and enlarged. London, Gerald Duckworth & co. ltd., 1949. 481 p.
23. Agricultural climatology of Siberia, natural belts, and agro-climatic analogues in North America. M. Y. Nuttonson. Wash., 1950. 64 p. (American institute of crop ecology. International agro-climatological series. Study no. 13).
24. Ecological crop geography of Finland and its agro-climatic analogues in North America. M. Y. Nuttonson. Wash., 1950. 35 p. (American institute of crop ecology. A research organization devoted to problems of plant adaptation and introduction). International agro-climatological series. Study no. 10).
25. Ecological crop geography of Norway and its agro-climatic analogues in North America. M. Y. Nuttonson. Wash., 1950. 31 p. (American institute of crop ecology. International agro-climatological series. Study no. 12).
26. Agricultural climatology of Sweden and its agro-climatic analogues in North America. M. Y. Nuttonson. Wash., 1950. 27 p. (American institute of crop ecology. International agro-climatological series. Study no. 11).
27. Shrubs of West Virginia. Nelle Ammons. Morgantown, 1950. 127 p. plates. (West Virginia university. Herbarium. Contribution no. 55).
28. Cretaceous plants from Southwestern Colorado. Roland W. Brown. Wash., Government printing office, 1950. (U.S. Department of the interior. Geological survey. Professional paper 221-D. Shorter contributions to general geology, 1949. pp. 45-66).

CHEMISTRY—CHEMIC TECHNOLOGY—BIOCHEMISTRY

29. A German-English dictionary for chemists. Austin M. Patterson. Third edition. New York, John Wiley & sons, inc., 1950. 541 p.
30. Proceedings of the fourth Industrial waste conference, Purdue university, 1948. Lafayette, 1949. 327 p. figs. tabs. (Purdue university. Engineering extension department. Extension series no. 68).
31. The extraction of oil from oil-bearing materials by prepressing followed by solvent extraction. Homer E. Rea, jr. and A. Cecil Wamble. College Station, 1950. 9 p. (processed) (Texas engineering experiment station. Research report no. 11).
32. Composition of flour from the 1948 potato crop. R. H. Treadway and others. Phila., 1950. 7 p. (processed) (U.S. Department of agriculture. Bureau of agricultural and industrial chemistry. Eastern regional research laboratory. AIC-277).
33. Western Australia. Government chemical laboratories. Annual report of the director, 1947. Perth, Government printer, 1950. 27 p.
34. Manufacture of cellulose pulps from straw. S. I. Aronovsky. Peoria, Illinois, 1950. 8 p. (processed) (U.S. Department of agriculture. Bureau of agricultural and industrial chemistry. Northern regional research laboratory. AIC-280).
35. Advances in enzymology and related subjects of biochemistry. Volume X. Edited by F. F. Nord. New York, Interscience publishers, inc., 1950. 533 p. References at end of chapters.

COOPERATION

Rural Wales. A yearbook of Welsh agricultural co-operation 1949-50. Aberystwyth, Welsh agricultural organisation society, ltd., 1950. 96 p.

DAIRY INDUSTRY—DAIRY RESEARCH

37. American dairy science association. Western division. Proceedings of the thirty-first annual meeting, Utah state agricultural college, Logan, Utah, July, 1950. n.p. (processed).
38. Dairy education in 1950. E. L. Crossley. (British dairy farmer's association. Journal, vol. LIV, 1950. pp. 16-32).
39. Utilization of Wisconsin milk. Emery C. Wilcox and others. Issued by Wisconsin state department of agriculture, Federal-State crop reporting service in co-operation with U.S. Department of agriculture. Production and marketing administration, and Bureau of agricultural economics. 113 p. (Special bulletin no. 3).

ECONOMIC POLICY

40. The Brannan plan. John Kerr Rose. Wash., 1950. 75 p. (processed) (U.S. Library of congress. Legislative reference service. Public affairs bulletin no. 78).
41. A history of Canadian external relations. G. P. deT. Glazebrook. Toronto, Oxford, 1950. 449 p.
42. Problems of African development. Part II. Government and people. T. R. Batten. London, Oxford university press, 1948. 180 p.
43. Economics as applied to government fiscal policy and debt management. Address by H. Christian Sonne before the students and faculty of Antioch College, Yellow Springs, Ohio, May 15, 1950. New York, Sanders printing corp., 1950. 29 p.

ECONOMIC STUDIES—ECONOMIC SURVEYS

44. Economic study of the dairy-herd-improvement-association two-successive-milkings tests compared with monthly average milk plant tests. 100 New York farms, September, 1947 through August, 1948. E. G. Misner. Ithaca, 1950. 44 p. (processed) (New York State college of agriculture, Cornell university agricultural experiment station, Department of agricultural economics. A. E. 739).
45. Harvesting hay and silage. Albert P. Brodell and Charles G. Carpenter. Wash., 1950. 17 p. (processed) (U.S. Department of agriculture. Bureau of agricultural economics. FM—79).
46. Methods of calculating depreciation of farm machinery. R. G. Murphy and R. C. Suter. Ithaca, 1950. 19 p. (processed) (New York state college of agriculture. Department of agricultural economics. A. E. 729).
47. Mexico. W. W. McVittie. Published for the Board of trade, Commercial relations and exports departments. London, H. M. stationery office, 1949. 55 p. (Overseas economic surveys).
48. Netherlands. L. B. S. Larkins. Published for the Board of trade, Commerical relations and exports departments. London, H. M. stationery office, 1949. 90 p. (Overseas economic surveys.)
49. Denmark. S. Simmonds. Published for the Board of trade, Commercial relations and exports departments. London, H. M. stationery office, 1949. 91 p. (Overseas economic surveys).
50. Portuguese East Africa. Cyril W. Andrews. Published for the Board of trade. London, H. M. stationery office, 1949. 48 p. (Overseas economic surveys).

ECONOMICS

51. Economic analysis and political synthesis. Edwin G. Nourse. (American philosophical society. Proceedings, vol. 94, no. 4, August 25, 1950, pp. 311-316). R. A. F. Penrose jr., memorial lecture.

EDUCATION

52. Agricultural education in community schools. Herbert M. Hamlin. Danville, Ill., The interstate, 1949. 487 p.
53. The function of the university. R. S. K. Seeley. London, Oxford university press, 1948. 79 p.

ENGINEERING—MACHINERY

54. Design and operation of drainage pumping plants. John G. Sutton. Wash., 1950. 81 p. figs. plates. (U.S. Department of agriculture. Technical bulletin no. 1008).
55. Building a plywood silo. R. O. Gilden and J. Roberts. Pullman, 1950. 21 p. figs. (Washington state college. Agricultural experiment stations. Popular bulletin no. 198).
56. Pen-type dairy barns. L. H. Brown and others. East Lansing, 1950. 32 p. figs. (Michigan state college. Agricultural experiment station. Special bulletin 363).
57. Electric light and power systems for the farm. H. H. DeLong. Brookings, 1950. 23 p. figs. (South Dakota state college. Agricultural engineering department. Agricultural experiment station. Bulletin 402).
58. Protection of buildings and farm property from lightning. R. N. Covert, L. P. Harrison, and H. L. Garver. Wash., 1950. 32 p. figs. (U.S. Department of agriculture. Farmers' bulletin no. 1512, revised).
59. Field machinery. Cornelius Davies. London, Nelson, 1949.

FEEDING AND FEEDING STUFFS

60. Grass silage for dairy cattle. B. W. Henderson, jr. and C. L. Norton. Kingston, 1950. 20 p. tabs. (Rhode Island state college. Agricultural experiment station. Bulletin 311).
61. The garbage hog feeding business in California. Wallace Sullivan and others. Berkeley, 1950. 18 p. figs. (California. University. Agricultural extension service. Circular 166).
62. The feeding value of stubble-rapes (late turnips). N. D. Dijkstra. The Hague, 1950. 39 p. English summary: pp. 32-33. (Holland. Ministerie van landbouw, visserij en voedselvoorziening. Directie van de landbouw. Verslagen van landboukundige onderzoekingen. No. 56.4).
63. Sorghum fodder for wintering bred ewes. Leslie E. Johnson and George E. Staples. Brookings, 1949. 8 p. tabs. (South Dakota agricultural experiment station. Bulletin 395).

FERTILIZERS

64. Soil fertility and sewage; an account of pioneer work in South Africa in the disposal of town wastes. J. P. J. Van Vuren. Foreword by Lady Howard. London, Faber and Faber, 1949. 236 p. il. tabs. graphs.
65. Man on the landscape; the fundamentals of plant conservation. Vernon Gill Carter. Wash., National wildlife federation, 1949. 129 p. figs.
66. Response of crops to various phosphate fertilizers. L. E. Ensminger. Auburn, 1950. 39 p. figs. tabs. (Alabama polytechnic institute. Agricultural experiment station. Bulletin no. 270).
67. Boron, copper, manganese, and zinc requirement tests of tobacco. C. W. Bacon and others. Wash., 1950. 27 p. tabs. (U.S. Department of agriculture. Technical bulletin no. 1009).
68. Poultry manure as a fertilizer for vegetable crops. E. M. Rahn. Newark, 1949. 18 p. figs. tabs. (Delaware. University. Agricultural experiment station. Bulletin no. 281.)
69. A guide to the uptake of plant nutrients by farm crops. D. J. Halliday. Bracknell, Berks, 1948. 34 p. figs. (Jealott's Hill research station. Imperial chemical industries ltd. Bulletin no. 7).
70. The influence of fertilizer usage on organic matter in soils: a literature survey. D. J. Halliday. Bracknell, Berks, 1950. 23 p. tabs. (Jealott's Hill research station. Imperial chemical industries ltd. Bulletin no. 8).
71. Fertilizers for early cabbage, tomatoes, cucumbers and sweet corn. John Bushnell. Wooster, 1950. 40 p. tabs. (Ohio agricultural experiment station. Research bulletin 697).

FOOD

72. Foods; their selection and preparation. Revised edition. Louise Stanley and Jessie Alice Cline. Boston, Ginn and company, 1950. 389 p. il. tabs.
73. Campbell's book; a manual on canning, pickling and preserving. Third edition. Clyde H. Campbell, revised by Rohland A. Isker and Walter A. Maclinn. Chicago, Vance publishing corporation, 1950. 222 p. il.
74. Composition of foods—raw, processed, prepared. Bernice K. Watt and Annabel L. Merrill. Wash., 1950. 147 p. (processed) (U.S. Department of agriculture. Agriculture handbook no. 8).

FOOD—Concluded

75. Flavor, texture, color, and ascorbic acid content of home-dehydrated vegetables and fruits. Elsie H. Dawson and others. Wash., 1950. 66 p. figs. tabs. (U.S. Department of agriculture. Technical bulletin no. 997).
76. Preservation of meat and meat products in frozen storage. P. T. Zeigler and others. State College, 1950. 24 p. figs. tabs. (Pennsylvania state college. Agricultural experiment station. Bulletin 530).

FORESTS AND FORESTRY

77. British Columbia. Department of lands and forests. Forest service. Annual report, 1949. Victoria, 1950. 141 p. il.
78. Forest plantations in the Lake States. Paul O. Rudolf. Wash., 1950. 171 p. figs. tabs. (U.S. Department of agriculture. Technical bulletin no. 1010).

GRAIN

79. Wheat in a Victorian bulk depot. F. Wilson. Melbourne, 1949. 47 p. figs. tabs. (Australia. Commonwealth scientific and industrial research organization. Bulletin no. 244).
80. Grain. Wash., 1950. 116 p. charts. (Food and agriculture organization of the United nations. Commodity series. Bulletin no. 18).

HORTICULTURE

81. A history of horticulture in America to 1860. U. P. Hedrick. New York, Oxford university press, 1950. 551 p. plates. bibliography: pp. 515-523.
82. The care and repair of ornamental trees. A. D. C. LeSueur. London, Country life limited, revised, 1949. 224 p. plates.
83. Fruit science; orchard and small fruit management. Norman Franklin Childers. Edited by R. W. Gregory. Chicago, J. P. Lippincott company, 1949. 630 p. figs. tabs. Suggested collateral readings at end of chapters.
84. The science of turf cultivation. R. P. Faulkner. London, Technical press ltd., 1950. 64 p. figs.
85. East Malling research station. Annual report, 1949. East Malling, Kent., 1950. 187 p. figs. tabs.
86. The dahlia year book, 1949. Wembley, Middx., The National dahlia society, (1949) 87 p. il.
87. A fuchsia survey. W. P. Wood. London, Williams & Norgate, Ltd., 1950. 170 p. il.
88. American tomato yearbook, 1950. John W. Carncross, editor. New York, C. S. MacFarland, jr., 1950. 36 p.
89. Tree peonies. Brookville, L.I., Louis Smirnow, n.d. 12 p.
90. Imperida: A new bunching carrot. DeLance F. Franklin. Moscow, 1950. 3 p. il. (Idaho. University, Agricultural experiment station. Circular no. 116).
91. Ralph Cusack, Uplands, Roundwood, Co. Wicklow, No. 1 list. Rare and uncommon bulbs. Autumn, 1950. 63 p.

INSECTS—PESTS

92. A manual of agricultural helminthology. I. N. Filipjev and J. H. Schuurmans Stekhoven. Leiden, E. J. Brill, 1941. 878 p. il. tabs. Bibliographies at end of sections.
93. Biology of Drosophila. M. Demerec, editor. New York, John Wiley & sons, inc., 1950. 632 p. figs. References at end of chapters.
94. The morphology and phylogeny of Auchenorhynchous Homoptera (Insecta). Sol Kramer. Urbana, University of Illinois press, 1950. 111 p. (Illinois biological monographs, vol. XX, no. 4).
95. Description de quelques pucerons, vecteurs de maladies à virus de la pomme de terre; leur denombrement dans les cultures. J. Münster. Lausanne, Station fédérale d'essais et de contrôle de semences, (1950) 7 p. figs. (processed).
96. White-fringed beetles and how to combat them. H. C. Young and others. Wash., 1950. 15 p. figs. (U.S. Department of agriculture. Circular no. 850).
97. Investigations on Agrilus sinuatus Oliv. S. Leefmans. Wageningen, 1950. 36 p. (Instituut voor plantenziektenkundig onderzoek. Mededeling no. 4). English summary: pp. 34-36.

INSECTS—PESTS—(Concluded)

98. An improved syringe hydrometer. C. V. Bowen. Wash., 1950. 3 p. il. (processed) (U.S. Department of agriculture. Bureau of entomology and plant quarantine. ET-290).
99. Tests of insecticides for grasshopper control, 1948 and 1949. Compiled by J. R. Parker. Wash., 1950. 27 p. (processed) (U.S. Department of agriculture. Bureau of entomology and plant quarantine. E-807).

LIVE STOCK—BREEDING

100. Sheep management and diseases. H. G. Belschner. Sydney, Angus and Robertson, 1950. 718 p. figs. col. plates. References at end of chapters.
101. Fat lamb production. Sheep crossing experiments conducted at Askham Bryan, York, 1930-1939. Leeds, University of Leeds and Yorkshire council for agricultural education, n.d. 32 p.
102. Alberta livestock co-operative limited. Report of annual meeting, 1950. Edmonton, 1950. v.p. (processed)

MARKETING—TRANSPORTATION

103. Cooperative dairy marketing in Sweden. Leland Spencer. Ithaca, 1950. 13 p. (processed) (New York state college of agriculture. Department of agricultural economics. Cornell university agricultural experiment station. Bulletin A. E. 734).
104. Historical development of transport coordination and integration in the United States. Wash., Interstate commerce commission. Bureau of transport economics and statistics, 1950. 217 p. (processed)
105. Milk marketing problems in North Carolina. Walter P. Cotton. Raleigh, 1950. 97 p. figs. (North Carolina state college. Agricultural experiment station. Bulletin no. 370.)
106. The New Zealand co-operative pig marketing association limited. 18th annual report. Auckland, 1950. 22 p.

NUTRITION—VITAMINS

107. A story of nutritional research. Sir Edward Mellanby. Baltimore, The Williams and Wilkins company, 1950. 454 p. figs. plates. tabs. references: pp. 437-443.
108. Calorie requirements. Report of the Committee on calorie requirements. Wash., Food and agriculture organization of the United nations, 1950. 65 p. tabs. (F A O nutritional studies. No. 5).

PASTURES—RANGES

109. Forage crops. Gilbert H. Ahlgren. New York, McGraw-Hill, 1949. 418 p. il. tabs. References at end of chapters.
110. Evergreen pastures. Annual, 1950. Ayr, McGill & Smith, ltd., 1950. 64 p. il.
111. Growing alfalfa for seed in Utah. Logan, 1950. 72 p. figs. (Utah agricultural experiment station. Circular 125).
112. New forage varieties for North Carolina. C. H. Hanson. (Research and farming (North Carolina A.E.S.) Special pasture edition, July, 1950, pp. 24-25).

PERSONNEL MANAGEMENT

113. Personnel management. W. D. Scott, R. C. Clothier and W. R. Spriegal. 4th edition. New York, McGraw-Hill, 1949. 648 p. il. charts. tabs. bibliography: pp. 603-631.
114. The office supervisor. Henry E. Niles and Mary C. H. Niles. 2d edition. New York, Wiley, 1949. 269 p. bibliography: pp. 257-262.

PHYTOPATHOLOGY

115. Verticillium wilt of peppermint. Ray Nelson. East Lansing, 1950. 259 p. figs. plates. Literature cited: pp. 255-259. (Michigan state college. Agricultural experiment station. Department of botany and plant pathology. Technical bulletin 221).
116. Canadian plant disease survey. Twenty-ninth annual report. Compiled by I. L. Conners and D. B. O. Savile. Ottawa, Department of agriculture. Science service. Division of botany and plant pathology, 1950. 114 p. (processed)
117. Charcoal rot of sorghum. D. F. Wadsworth and J. B. Sieglinger. Stillwater, 1950. 7 p. (Oklahoma agricultural experiment station. Bulletin no. B-335).
118. Visualization of tobacco mosaic virus within infected cells. L. M. Black and others. (Reprinted from Proceedings of the Society for experimental biology and medicine, vol. 73, 119-122, 1950) (Brooklyn botanic garden. Contributions. No. 111).

PLANT BREEDING—PLANT GROWTH

119. Corn improvement conference of the North Central Region. 11th report, Chicago, 1950. Beltsville, Maryland, U.S. Department of agriculture. Bureau of plant industry, soils, and agricultural engineering, 1950. 57 p. (processed).
120. The national onion-breeding program, 1949. Beltsville, U.S. Department of agriculture. Bureau of plant industry, soils, and agricultural engineering, 1950. 87 p. (processed).
121. Radioactive materials as plant stimulants—field results. Lyle T. Alexander. (Reprint from Agronomy journal, vol. 42, no. 5, May, 1950, pp. 252-255).

REPORTS, MISCELLANEOUS—YEARBOOKS

122. National grange. Journal of proceedings, eighty-third annual session, Sacramento, California, 1949. Baltimore, Waverly press, (1950). 239 p. il.
123. International bank for reconstruction and development. Fifth annual report, 1949-1950. Wash., 1950. 64 p.
124. National federation of women's institutes. Thirty-third annual report, 1949. London, (1950) 41 p.
125. Port of New York authority. Twenty-ninth annual report, 1949. New York, 1950. 148 p. il.
126. Smithsonian institution. Annual report, 1949. Wash., Government printing office, 1950. 422 p. il.
127. Yearbook of food and agricultural statistics, 1949. 1. Production. Wash., Food and agriculture organization of the United nations, 1950. 313 p. (processed).

SOILS—CONSERVATION—IRRIGATION

128. Dredge drain reclaim. Joh. van Veen. 2d ed. The Hague, Netherlands, Martinus Nijhoff, 1949. 165 p. il. photos. maps (col.). charts.
129. Conservation irrigation. Allan W. McCulloch and Wayne D. Criddle. Wash., 1950. 15 p. il. tabs. (U.S. Department of agriculture. Agriculture information bulletin no. 8).
130. Western land and water use. Mont. H. Saunderson. Norman, University of Oklahoma press, 1950. 217 p. plates. bibliography: pp. 208-212.
131. Dynamique du sol. Quatrième édition. Albert Demolon. Paris, Dunod., 1948. 414 p. figs. tabs. (Principes d'agronomie. Tome I).
132. Proposed practices for economic analysis of river basin projects. Report to the Federal inter-agency river basin committee. Prepared by the Subcommittee on benefits and costs. Wash., 1950. 85 p.
133. Costs and benefits from soil conservation in northeastern Illinois. E. L. Sauer and others. Urbana, 1950. pp. 563-596. il. tabs. (Illinois. University. Agricultural experiment station. Bulletin 540).
134. Permeability studies on some Illinois soils. C. A. Van Doren and A. A. Klingebiel. Wash., 1950. 13 p. figs. tabs. (processed) At head of title: U.S. Department of agriculture. Soil conservation service.
135. The use of agricultural soil maps and the status of agricultural soil mapping in the United States. Wash., 1949. 128 p. maps. (processed) (U.S. National research council. Division of engineering and industrial research. Highway research board. Bulletin no. 22) Title on cover: Engineering use of agricultural soil maps.

SOILS—CONSERVATION—IRRIGATION—Concluded

136. New South Wales. Water conservation and irrigation commission. Annual report, 1949. Sydney, 1950. 59 p.
137. Soil survey report of southeastern New Brunswick. H. Aalund and R. E. Wicklund. Issued by Experimental farms service, Dominion department of agriculture in cooperation with the New Brunswick department of agriculture. Fredericton, 1949. 108 p. il. tabs. maps (col.). (New Brunswick soil survey reports. No. 3).

STATISTICAL METHODS

138. Introduction to the theory of probability and statistics. Niels Arley and K. Rander Buch. New York, Wiley, 1950. 236 p. (Applied mathematics series).

TEXTILES

139. The Australian wool industry. H. Munz. Sydney, Angus and Robertson, 1950. 162 p. figs. plates. bibliography: p. 155.
140. Physical properties of plated fabrics knit of cotton, wool, viscose rayon, and nylon. Hazel M. Fletcher and others. Wash., 29 p. figs. (U.S. Department of agriculture. Circular no. 848).

TRADE

141. The United States and the restoration of world trade. William Adams Brown, jr. Wash., Brookings institution, 1950. 572 p.
142. Agriculture, trade and reciprocal trade agreements. Lawrence W. Witt. East Lansing, 1950. 43 p. (Michigan state college. Agricultural experiment station. Department of agricultural economics. Technical bulletin 220).

VETERINARY MEDICINE

143. Animal sanitation and disease control. R. R. Dykstra. revised and enlarged. Danville, Ill., Interstate, 1949. 808 p. figs.
144. Veterinary obstetrics. W. L. Williams. Fourth edition. Worcester, Mass., Ethel Williams Plimpton, 1948. 483 p. figs. plates (col.) bibliography: pp. 471-473.

ZOOLOGY

145. Animals of the Canadian Rockies. Dan McCowan. Toronto, Macmillan, 1950. 302 p.
146. Biology of the vertebrates. Herbert E. Walter and Leonard P. Sayles. Third edition. New York, Macmillan, 1949. 875 p. figs. bibliography: pp. 833-835.